HAMILTON HARBOUR STUDY 1977

MATERIAL INPUTS TO HAMILTON HARBOUR

Prepared by: W.J. Snodgrass
Water Research Group
Civil and Chemical Engineering
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FOREWORD

This report is the second of a two volume set of technical reports which deal with the water quality, and the physical, chemical and biological processes in Hamilton Harbour during 1977.

This report was prepared by Dr. W. Snodgrass of McMaster University in partial fulfillment of purchase order #A54920.

The summary was prepared by Mr. D. Decaire, and the report was edited by Dr. R. Weiler and Mr. D. Decaire of the Water Resources Branch.

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SUMMARY

This report consists of a compilation of data concerning the hydrology of and waste loadings into Hamilton Harbour together with comparisons and interpretations of these data collected by various agencies. The harbour is classified as hypereuthrophic with a mean chlorophyll _a_ level of about 20 ug/L and total phosphorus of about 80 ug/L. Management options and philosophies are briefly outlined in the conclusions of Section 6.

In Section 2, it was concluded that in seeking rainfall - runoff correlations, use of rainfall data from one station is justified rather than constructing a Thiessen network for each drainage basin. The data from stream flows and runoff were derived from stream gauges, yield coefficients and rainfall - runoff correlations. Various estimates for harbour water detention time are compared, and the need for further measurements and calculations over a few years is suggested.

Section 3 consists of a description of the characteristics of wastes expected from the various processes in an integrated steel mill, followed by a typing of the wastes discharged from Stelco and Dofasco. The industrial waste loading data were obtained principally from reports by industry, the Ontario Ministry of the Environment and from Environment Canada. In view of the varying degrees of reliability associated with the industrial waste loadings, a comparison of the estimates is presented and a suggestion is made as to what is deemed the most appropriate.

Section 4 addresses the municipal wastewater treatment plants on the Hamilton Harbour watershed, namely the Hamilton WWTP, the Burlington Skyway Plant and the Dundas WWTP. The treatment efficiencies for these plants are described and loadings for the most commonly used chemical and biochemical indicators of performance are tabulated.

In Section 5 the sources of stormwater and surface water are described and quantified. The use and calibration of mathematical models is discussed and comparisons are made between the methodologies employed by James F. MacLaren Limited, Gore and Storrie Limited, Proctor and Redfern Limited and the Canada Centre for Inland Waters.

For quality predictions, the weaknesses of the unit load approach is that it assumes constant conditions from year to year. It is concluded that for those chemical parameters dominated by inputs from surface water runoff, annual variations in hydrological inputs affect the year by year variation of harbour water quality.

In Section 6 the data for the annual average loadings to Hamilton Harbour are summarized for twenty-two parameters in Tables 6.2a and 6.2b, entitled "Percentage of Inputs to Harbour from Major Sources". By using the relationship - Total Dissolved Solids = 0.65 (conductivity), the total dissolved loading to the harbour is 607,000 kg/day. For total nitrogen and ammonia the loadings are 5,000 kg/day and 2,000 kg/day, respectively. Total phosphorus input is 620 kg/day, and for other parameters a tabulation is made in Table 6.1.

The appendices contain graphs and tables concerning sewer flows, stream loadings and surface water quality data. The methods of calculating loadings to water bodies are described in Appendix A.2.

MATERIAL INPUTS TO HAMILTON HARBOUR
1971-1977

1.0 INTRODUCTION

Hamilton Harbour (also known as Burlington Bay) is a naturally occurring part of Lake Ontario which was cut off from the lake by formation of a sand-bar. Over recorded history (ie. since settlement of Southern Ontario), the bar has generally been breached by a channel. Since the early 1900's a permanent channel to permit shipping access to the harbour has been maintained by dredging and construction of jetties. Between 1926 and 1939, the channel cross-section was enlarged from 44 m x 5.4 m to 88 m x 7.8 m (Dick and Marsalek, 1973). From 1939 onward, the channel has gradually been extended to its present 1977 dimensions of 107 m x 9.5 m (Kohli, 1977). Between 1926 and 1969, landfilling, which has occurred primarily in areas adjacent to the sand-bar and to Hamilton's industrial area, decreased the volume from 295×10^6 m^3 to 287×10^6 m^3 and the surface area from 28.2×10^6 m^2 to 22.0×10^6 m^2 (Dick and Marsalek, 1973).

The amount of surface runoff to the harbour has been influenced by changes in infiltration characteristics due to urbanization and by a small expansion of the drainage area through the transfer of approximately 10 km^2 from the Lake Ontario watershed to the Hamilton Harbour watershed. A more significant impact has been the substantial increase in municipal consumption of water since the water supply is taken from Lake Ontario and the contaminated water is discharged to the harbour. This, coupled with expansion of the ship channel and its attendant increased lake-harbour exchange, has fundamentally changed the hydraulic characteristics of the harbour.

The urbanization and industrialization of the Harbour's watershed have also influenced the water quality in the harbour. At present, approximately 370,000* people occupy the watershed together with a

large industrial infrastructure including Canada's two largest steel mills. The sanitary sewerage of approximately 450,000* people are treated and then discharged to the harbour. The harbour is presently classified as hypereutrophic, with mean chlorophyll a levels of about 20 ug/L and total phosphorus of about 80 ug/L.

The relationships between water quality and human activities can be assessed by estimating the rate of inputs (loadings) of various pollutants to the water body and then by constructing water quality models of differing degrees of sophistication to answer specific questions concerning the relationships of loadings to water quality. The objective of this report is to estimate the loadings of various materials to the harbour for the year 1977.

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*Estimates based on: Hamilton-306,000; Dundas-17,000; Ancaster-15,000; Burlington-sanitary sewerage from 90,000; storm water discharges from 30,000; Stoney Creek-sanitary sewerage from 25,000, estimated from 6,235 water meters at 4 people/meter).

2.0 HYDROLOGY OF HAMILTON HARBOUR

2.1 INTRODUCTION

The area of each watershed of Hamilton Harbour is shown in Table 2.1; Figure 2.1 is a map of the watersheds. The total drainage area of 494×10^6 m^2 gives a drainage area to harbour surface area ratio of 23. Cootes Paradise, Grindstone Creek and Red Hill Creek are the major watersheds. Hamilton stormwater overflows drain the combined stormwater - sanitary sewerage from the area of Hamilton below the mountain. While the area is small, the impact on the harbour can be large due to the substantial pollutant load of the overflows.

2.2 RUNOFF MODELLING AND ESTIMATION

As some watersheds, including the storm sewers, are not gauged, it is necessary to estimate the quantity of water drained from such areas. Various hydrological tools are available, ranging from event-based rainfall-runoff models such as the Stanford Watershed Model (an elaborate book-keeping model), HYMO (developed for agricultural watersheds) and SWMM (developed for urban catchments) to coarse estimates of runoff based upon such techniques as rainfall-runoff correlations or yield coefficients (the annual average rate of runoff per unit area for a region).

The event-based models are quite precise as they are generally verified to make predictions of peak rate of flood flow, but they are unsuitable for estimating daily flows as they are poor predictors of low flow rates between storm events. The models also are computationally intensive. The second group of techniques are computationally non-intensive and less precise, but useful for estimating average flows over time scales of months or years. These latter methods have been adopted for this section.

2.2.1 Rainfall and Catchment Areas

Functional relationships between annual runoff rate and other parameters were sought. The rainfall patterns of Hamilton Harbour were calculated by constructing a Thiessen network composed of rainfall stations at the Municipal Laboratory, Hamilton Airport and Royal Botanical Gardens and adjoining stations. The results shown in Table 2.2 indicate that there is substantial year to year variation for the Harbour or for any one recording station (Royal Botanical Garden in Table 2.2, or Milgrove in Table 2.3) but a relatively small variation between the network estimates and those of any one station. Accordingly, it was concluded that in seeking rainfall-runoff correlations, use of rainfall data from one station is justified rather than constructing a Thiessen network for each drainage basin.

Annual runoff rates for Grindstone Creek and Spencer Creek are compared to annual precipitation at Milgrove in Table 2.3 for the period 1965 to 1977. Plots of runoff versus rainfall show a significant correlation with a wide scatter. The slope of the regression line - runoff in inches = 0.41 x rainfall in inches - is significant at the 1% level. Plots of monthly rainfall against monthly runoff showed similar scatter. It has been observed by hydrologists that there is often a relationship between runoff flows in adjoining basins of the form $Q_1/Q_2 = (A_1/A_2)^n$ where Q_i and A_i are respectively the flow rate and drainage area of watershed i and n is a coefficient varying from 0.75 to 1. This relationship arises from the fact that small watersheds have larger peak flows per unit area than large watersheds. For annual flows or monthly flows, plots show that n is not much different from 1 for Grindstone Creek and Spencer Creek. Because there does not appear to be a significant advantage to using a rainfall-runoff relationship in preference to a yield coefficient in estimating monthly or annual flows from ungauged areas, the latter are used for surface flow estimation.

Table 2.4 shows the annual average flows for all of the different watersheds of Hamilton Harbour and for the wastewater treatment discharges. These flows, together with the exchange between Lake Ontario and the harbour and direct rainfall, represent all of the hydraulic flows into the harbour. The Burlington surface discharges were assigned the yield coefficients of Grindstone Creek while the ungauged areas of Cootes Paradise and the Red Hill Creek watershed were assigned the yield coefficients of Spencer Creek. The municipal wastewater flows were obtained from plant records.

It is difficult to estimate flows from downtown Hamilton as the whole area is serviced by combined sewers. A conservative approach would be to assume that the majority of rainfall - perhaps 90% - which falls on this area reaches the harbour directly; that is, sanitary sewerage (dry weather flow) is piped to the wastewater treatment plant (WWTP) while the majority of stormwater flow is discharged to the harbour. The actual picture is more complex. A cross-town interceptor was constructed in the 1960's. This interceptor collects dry weather flow plus a significant portion of stormwater flow, depending upon the storm intensity and the opening/closing sequences of the overflow gates. Studies described in Section 5 and summarized in Table 2.4 suggest that a significant portion of this area is pervious (an infiltration coefficient of 0.51 for the James St. - Wellington St. catchments) and that of the order of one-quarter of the rainfall - 24 cm runoff from 90 cm rainfall - is discharged to the harbour by stormwater overflows. This rainfall-runoff ratio and the annual rainfall are used to estimate stormwater overflows from the downtown areas of Hamilton.

2.2.2 Detention Time

The natural detention time of the harbour on an annual basis varied from 1.2 years to 1.8 years for the period of 1975-1977 (see Table 2.4). This estimate includes the modifying effects of urbanization on surface runoff but excludes wastewater treatment plant discharges. Hamilton, Dundas and Burlington obtain their drinking water from Lake Ontario, and discharge the waste water to the harbour. This discharge, which represents from 33% to 50% of the total inflow during the 1975-1977 period, lowers the actual estimate of detention time to the range of 0.8-1.1 years.

An estimate of the monthly variation in detention time for the harbour is shown in Table 2.5. The assumptions for Table 2.4 were used. Based only on flows from surface streams, the detention time varies from 0.4 to 11 years. The effect of a fairly constant flow ($0.38 \simeq 0.4$) from the waste water treatment plants is to decrease the range to 0.3-2.3 years. Such variations suggest that for phenomena whose time scale of concern is of the order of a month, the results from models of water quality may be significantly affected if an average annual flow is used rather than actual flows.

2.2.3 Exchange Flows Between Lake Ontario and Hamilton Harbour

Hamilton Harbour is also affected by exchange with Lake Ontario and the East Pond of Cootes Paradise. The exchange with the harbour can have a significant effect upon Cootes Paradise (Ministry of the Environment, 1977; Kohli, 1979), but as the flow from Spencer Creek and other creeks causes the annual detention time to be small, it is assumed here that such exchange may be neglected. The exchange is equivalent to an average daily inflow of water and an outflow of water at the same rate. Such a parameterization may then be used to define a detention time based upon the volume of the harbour divided by the exchange flow rate, E (m^3/day). Such an exchange flow rate will vary hourly, daily, weekly and monthly, depending upon the time used for averaging the total exchange volume of water.

Transport of mass of material due to diffusion (Fick's first law) is equal to $D\,\partial c/\partial x$ where D is the diffusion coefficient and $\partial C/\partial x$ the concentration gradient or to $D(C_1 - C_2)/\Delta x$ where C_1 and C_2 are the concentrations between two points separated by a distance of Δx. The mass flow of material is $DA(C_1 - C_2)/\Delta x$ where A is a cross-sectional area through which transport occurs. If A is considered to be the cross-sectional area of the Burlington Ship Canal and if position 1 is in Hamilton Harbour and position 2 in Lake Ontario, then the mass transport out of the harbour is $DAC_1/\Delta x$ and in to the Harbour is $DAC_2/\Delta x$. The units of $DA/\Delta x$ are m^3/day, equivalent to a flow rate and in fact $DA/\Delta x$ is equal to E.

Weekly water levels in Hamilton Harbour are shown in Table 2.6 for 1975-1977. Observations are made daily by the Harbour police. As there are no substantial variations during a week except during high winds, weekly levels are adequate to describe variations over a year. While small variations in levels are found for the winter months in 1975 and 1976, substantial variations occurred during the rest of 1976. If inputs from surface streams were negligible, then these changes in level require a net exchange flow into the harbour (positive) or out of the harbour (negative). In 1975, the exchange flows are - January 15 to March 15: 1.3 m^3/s, March 15 to April 30: 1.7 m^3/s, July 1 to August 15: 1.7 m^3/s, August 15 to December 15: 0.57 m^3/s. In 1976, the flows for January 1 to May 1 are 1.9 m^3/s and for July 15 to December 1 are 1.7 m^3/s (1 cu ft = 0.0283 m^3). For 1977, the flows for March 9 to April 9 are 2.5 m^3/s after which the level remained constant. For periods not specified above, the harbour level remained approximately constant, meaning essentially no net exchange. Net exchanges due to wind events of less than a week are not ascertainable from data in Table 2.6.

An interesting question arises concerning the cause of variations of level of Hamilton Harbour - is inflow from the lake necessary to explain the increases in harbour water volume or are watershed inflows sufficient to cause the increases? Municipal discharges during the period (3.4 m^3/s) are always larger than the net exchange flows calculated from Harbour level variations. Hence lake inflows are not necessary to explain increases in Harbour level. Rather, the changes in the Harbour level can be visualized as being due to inflows from the watershed and a floating weir (in the Burlington Ship Canal) whose height varies seasonally. Hence lake-harbour exchange is caused by mechanisms other than lake level changes whose time scale is a month or greater.

Dick and Marsalek (1973) found that the Harbour exchange is of two types. The unidirectional flow, the so-called Helmholtz mode, changes direction depending upon the relative differences in lake and harbour levels and persists throughout the year. The densimetric flow has been observed only during thermal stratification and consists of warm harbour water flowing out to the lake in the top layer and colder lake water flowing in to the harbour in the bottom layer. Although they observed only two layer flow during stratification, MOE studies have occasionally found three distinct layers. Dick and Marselek built a mathematical model which shows that densimetric flow is small compared to flows resulting from level differences. Differences due to short-term variations (hourly water levels) were the dominant cause of the unidirectional flow since monthly variations had a negligible effect. As Lake Ontario levels change much more due to wind effects than do harbour levels, they conclude that short-term variations in Lake Ontario levels are the main driving force for exchange.

The model of Dick and Marsalek estimates an average annual exchange flow rate through the canal of 59 m^3/sec for 1971. The detention time based only on this exchange is 0.15 years; considering both exchange and hydraulic inputs the detention time is 0.13 years. The exchange rate is between five and nine times the hydraulic inflow rate during 1975-1977. Exchange rates calculated from their measurements of velocity profiles (ten experiments during 1971) were approximately the same as that calculated from this exchange flow rate. This provides some verification of their model predictions. Their model predicts that the widening and deeping of the canal has caused the exchange flow rate to increase by 30% since 1926, given the same fluctuations in lake elevations as in 1971.

Kohli (1977) analysed continuous current data in the ship canal to estimate exchange. An episode method was used in which the velocity and direction of currents are examined to determine those periods of time in which a particle of water has moved a sufficient distance from the lake to the harbour or visa versa to constitute exchange. The estimated exchange flows were 8 m^3/s from the lake to the harbour and 25 m^3/s from the harbour to the lake for the period of

September 1-13, 1975. The inflow rate from all other sources is estimated here as 6-8 m^3/s. Hence, there is a net outflow of about 10 m^3/s, which would cause a lowering of the harbour level of 0.5 m. However, the data on Table 2.6 show no decrease during this period. The detention time for this exchange flow is 1.1 years. When surface inflow is included, the detention time is 0.6 years. Such exchange flow is approximately equal to the inflow from land-based sources.

Kohli (1979) has made similar calculations of average exchange for the months of June, July, August, October, and November 1976. The exchange flow rates from the lake to the harbour are, respectively, 9.3, 1.6, 4.3, 10.8 and 16.7 m^3/s, which give detention times of 0.95, 5.5, 2.1, 0.8 and 0.5 years respectively based on exchange alone. Based upon both exchange and hydraulic inflows, the detention times are respectively 0.43, 0.69, 0.57, 2.5 and 0.32 years. The calculated average net outflow was 26.4 m^3/sec. As our estimates of the average inflow rate from all other sources is 11.2 m^3/sec, there must be a net lowering of the harbour equivalent to an outflow of 15.2 m^3/sec. This corresponds to a net lowering of approximately 9 meters during these 5 months. At present, this discrepancy cannot be unaccounted for.

Hence overall, the exchange calculations of Dick and Marsalek (1973) suggests that exchange flows are much greater than surface water runoff and point source discharges. The exact magnitude of exchange awaits proper mass budgets and calculation of exchange over a few years. This chapter aims to summarize all the present information known on mass budgets available to 1977.

TABLE 2.1
AREA OF HAMILTON HARBOUR WATERSHEDS

WATERSHED	AREA (square miles)
BURLINGTON AREAS	
(i) Grindstone Creek	30.3
(ii) Aldershot Drive	4.9
(iii) Falcon Creek	1.6
(iv) Burlington Open Channel (Rambo-Hager Diversion)	8.7
COOTES PARADISE	
(i) Spencer Creek (Gauge at railway underpass)	64.0
(ii) Ungauged Area*	43.0
(iii) Red Hill Creek	26.6
HAMILTON STORM WATER OVERFLOWS	
(i) Queen Street	0.27
(ii) Caroline	0.13
(iii) Marshall	0.093
(iv) James	0.13
(v) Catherine - Ferguson - Wellington	1.82
(vi) Wentworth	1.43
(vii) Birch	0.48
(viii) Gage	1.93
(ix) Ottawa	0.39
(x) Kenilworth	1.46
(xi) Strathearne	1.70
(xii) Parkdale	0.75

*Composed of Spencer Creek Catchment below gauge, Hickory Creek, Long Valley Brook, Vine Brook, Hopkins Creek, Westdale Brook and Chedoke Creek (3.8 sq mi). The area of Hamilton Harbour is 8.3 sq. mi. To convert to square metres multiply areas by 2.6×10^6.

TABLE 2.2
ANNUAL PRECIPITATION FOR HAMILTON HARBOUR

YEAR	ROYAL BOTANICAL GARDEN (in)	THIESSEN NETWORK FOR HAMILTON HARBOUR (in)
1955		31.57
1956		37.11
1957		30.44
1958		27.84
1959		34.83
1960		31.98
1963		23.12
1964		34.43
1965		34.01
1966	30.54	32.66
1967	32.19	34.43
1968	36.67	35.58
1969	27.85	28.90
1970	31.53	30.24
1971	25.56	28.03
1972	38.64	39.37
1973	35.20	37.82
1974	32.79	32.80
1975	37.19	38.10
1976	34.24	36.20
1977	42.61	

TABLE 2.3
RELATIONSHIP OF RAINFALL TO RUNOFF IN GRINDSTONE CREEK AND SPENCER CREEK DRAINAGE AREAS

ANNUAL PRECIPITATION (MILLGROVE)		GRINDSTONE CREEK AT ALDERSHOT (02HB012)			SPENCER CREEK AT DUNDAS CROSSING		
		ANNUAL MEAN DISCHARGE		RUNOFF COEFFICIENT	ANNUAL MEAN DISCHARGE		RUNOFF ** COEFFICIENT
Year	Rate in/yr	cfs*	in/yr		cfs*	in/yr*	
1965	39.39	26.5	11.9	0.302	74.4	15.7	0.399
1966	34.25	21.9	9.8	0.286	48.0	10.2	0.298
1967	35.16	24.6	11.0	0.313	73.8	15.7	0.447
1968	34.53	36.8	16.5	0.478	68.7	14.6	0.423
1969	28.89	30.5	13.7	0.479	55.3	11.7	0.405
1970	30.94	21.0	9.4	0.304	45.3	9.6	0.310
1971	30.32	25.3	11.3	0.372	50.2	10.6	0.350
1972	41.05	41.0	18.4	0.448	78.2	16.6	0.404
1973	37.19	46.0	20.6	0.539	78.7	16.7	0.449
1974	31.86	36.4	16.3	0.512	72.8	15.4	0.483
1975	36.29	25.9	11.6	0.320	61.2	13.0	0.359
1976	33.85	43.3	19.4	0.573	95.9	20.3	0.599
1977	37.18	33.8	15.1	0.406	82.1	17.4	0.468
				$\bar{x}$ = 0.410;			$\bar{x}$ = 0.415;
				s = 0.100;			s = 0.080;
				n = 13			n = 13

* 1 cu. ft. = 0.0283 m^3; 1 in. = 2.54 cm.
** Runoff Coefficient = runoff (in)/rainfall (in)

TABLE 2.4

SUMMARY OF ANNUAL HYDRAULIC INPUTS FOR HAMILTON HARBOUR
1975 - 1977

OLOGIC BUDGET

	AREA OF WATERSHED (sq. mi.)*	ANNUAL AVERAGE FLOW (cfs)* FROM GIVEN WATERSHED IN YEAR 1975	1976	1977
dstone Creek	30.3	25.9	43.3	33.8
lington Discharge	9.7 (1975-76) 14.7 (1977)	9.2	15.	17.
otes Paradise) Spencer Creek at railway gauge	64.0	61.2	95.9	82.1
b) Remainder ungauged	43.0	42.	65.	56.
Red Hill Creek	26.6	26.	40.	34.
Hamilton Storm Water Overflows	10.6	7.8	7.1	8.9
(a) Hamilton WWTP		98.	103.	105.
(b) Burlington and Dundas WWTP		20.	26.	27.
TAL		290. (8.2)	395. (11.2)	364. (10.3) m^3/s

2.4 (b) DETENTION TIME ESTIMATES

DETENTION TIME ESTIMATED FROM AVERAGE ANNUAL FLOW FROM	YEAR 1975	1976	1977
(i) Land Runoff	1.8 yr	1.2 yr	1.3 yr
(ii) Total Hydraulic Input**	1.1	0.79	0.86

2.4 (c) SOURCES OF ESTIMATES

1. Grindstone Creek (gauged at Aldershot, Station 02HB012).
2. Burlington discharges (Aldershot Drive-4.9 sq. mi.; Falcon Creek-1.6; Burlington Open Channel, 4.3 from 1975-1976, 8.7 in 1977) obtained by using Grindstone Creek data and ratio of respective drainage areas.
3. Cootes Paradise - Spencer Creek gauge at Railway Underpass Station 02HB010; remainder ungauged - Spencer Creek data and ratio of respective drainage areas.
4. Red Hill Creek - Spencer Creek data and ratio of respective drainage areas.

* 1 sq. mi = $2.6 \times 10^6 m^2$; 1 cu. ft. = $0.0283 m^3$; 1 in. = 2.54 cm.
1 acre = 0.405 ha

** Total Hydraulic Input = Land Runoff plus WWTP Discharges

CON'T of TABLE 2.4

5. Hamilton Stormwater Overflows - average of 9.4 in. of overflow from 35 in. rain. Rainfall during particular year is used with the ratio of 9.4/35. The value of 9.4 is an average from following data:

STUDY	AREA	% IMPERVIOUSNESS	NUMBER OF OVERFLOWS	RUNOFF (in)*	AREA (acres)*	DATE OF STUDY
MacLarens (1978)	Wellington	55	41	7.8	657	Quantity from 1974-75
	Ferguson					data from
	Catharine					1977 data for
	James Street	47	41	6.9	612	both areas
Gore and Storrie (1977)	Upper Ottawa	36	20	-	176	1975-76
Proctor Redfern	Hamilton Mountain	41	26	11.3	2700	1974-75
Average		43		9.4		

Note MacLaren's study data is treated as one, rather than two areas for averaging purposes.

6. Hamilton WWTP flows from the annual plant reports; Dundas WWTP from MOE West-Central, Regional Office; Burlington WWTP from MOE Central Regional Office.

TABLE 2.5

MONTHLY VARIATION IN DETENTION TIME ESTIMATES BASED EITHER ON LAND RUNOFF OR LAND RUNOFF PLUS WWTP DISCHARGES

MONTH	DETENTION TIME* (yr)					
	1975		1976		1977	
	FLOW FROM LAND RUNOFF**	FLOW FROM ALL SOURCES***	FLOW FROM LAND RUNOFF	FLOW FROM ALL SOURCES	FLOW FROM LAND RUNOFF	FLOW FROM ALL SOURCES
January	2.9	1.4	2.3	1.2	7.0	1.7
February	1.2	0.83	0.44	0.37	4.3	1.2
March	0.61	0.49	0.33	0.28	0.38	0.32
April	1.0	0.74	0.78	0.58	0.83	0.59
May	2.9	1.4	0.95	0.68	3.6	1.4
June	6.8	2.0	3.6	1.5	6.7	1.7
July	11	2.3	3.9	1.6	5.2	1.9
August	5.9	1.8	7.5	2.0	6.1	1.7
September	2.7	1.3	1.6	0.97	1.4	0.86
October	2.4	1.3	2.5	1.2	1.0	0.70
November	1.6	1.0	3.2	1.5	1.2	0.81
December	1.6	0.94	5.0	1.7	0.69	0.52

* Detention time estimate is the time required to fully displace harbour volume of water at the respective monthly flow rate.

** Hydraulic detention time based upon flow from all stream and storm water discharges to the harbour.

*** Hydraulic detention time based upon flow from all streams, storm water discharges and the three waste water treatment plants (Hamilton, Burlington, Skyway and Dundas).

TABLE 2.6

ELEVATION OF HAMILTON HARBOUR SURFACE
1975 - 1977

DATE		ELEVATION* (ft)	DATE		ELEVATION* (ft)
(a) 1975			(a) 1975		
January	1	243.9	September	3	244.8
	8	244.1		10	244.6
	15	243.8		17	244.7
	22	243.9		24	244.6
	29	244.5			
February	5	244.5	October	1	244.5
	12	244.7		8	244.6
	19	244.5		15	244.6
	26	244.1		22	244.5
				29	244.3
March	5	244.8	November	5	244.2
	12	245.0		12	244.4
	19	245.0		19	244.3
	26	245.4		26	244.2
April	2	245.4	December	3	243.7
	9	245.4		10	244.1
	16	245.3		17	244.1
	23	245.7		24	244.1
	30	246.0		31	244.3
May	7	245.9	(b) 1976 January	7	244.1
	14	245.9		14	244.3
	21	245.8		21	244.2
	28	245.7		28	244.4
June	4	245.7	February	4	244.4
	11	245.8		11	244.2
	18	245.9		18	244.6
	25	245.9		25	244.9
July	2	245.8	March	3	245.5
	9	245.6		10	245.6
	16	245.4		17	245.6
	23	245.3		24	245.9
	30	245.2		31	246.3
August	6	245.2	April	7	246.6
	13	245.1		14	246.7
	20	244.8		21	246.9
	27	244.7		28	246.9

*ft. above mean sea level; 1 ft. = 0.3048 m.

CON'T TABLE 2.6

DATE		ELEVATION* (ft)	DATE		ELEVATION* (ft)
(b) 1976			(c) 1977		
May	5	247.0	January	5	244.0
	12	247.2		12	244.0
	19	247.2		19	244.0
	26	247.4		26	243.9
June	2	247.5	February	2	243.9
	9	247.3		9	244.3
	16	247.2		16	243.8
	23	247.1		23	244.0
	30	247.3			
July	7	247.0	March	2	243.5
	14	247.0		9	244.0
	21	246.7		16	243.9
	28	246.6		23	244.6
				30	244.9
August	4	246.5	April	6	245.1
	11	246.4		13	245.4
	18	246.1		20	245.2
	25	246.0		27	245.3
September	1	245.9	May	4	245.5
	8	245.6		11	245.4
	15	245.5		18	245.3
	22	245.3		25	245.3
	29	245.1			
October	6	245.2	June	1	245.3
	13	245.1		8	245.1
	20	245.0		15	245.1
	27	244.9		22	245.1
				29	245.1
November	3	244.8	July	6	245.2
	10	244.5		13	245.2
	17	244.4		20	245.3
	24	243.8		27	245.9
December	1	243.8	August	3	245.1
	8	244.1		10	245.4
	15	244.0		17	245.2
	22	243.6		24	245.2
	29	243.9		31	245.2

CON'T TABLE 2.6

DATE		ELEVATION* (ft)	DATE		ELEVATION* (ft)
(c) September 1977	7	245.3	November	2	245.0
	14	244.7		9	245.4
	21	245.1		16	245.1
	28	245.4		23	245.1
				30	244.9
October	5	245.4	December	7	244.9
	12	245.1		14	245.2
	19	245.1		21	245.7
	26	245.1		28	245.1

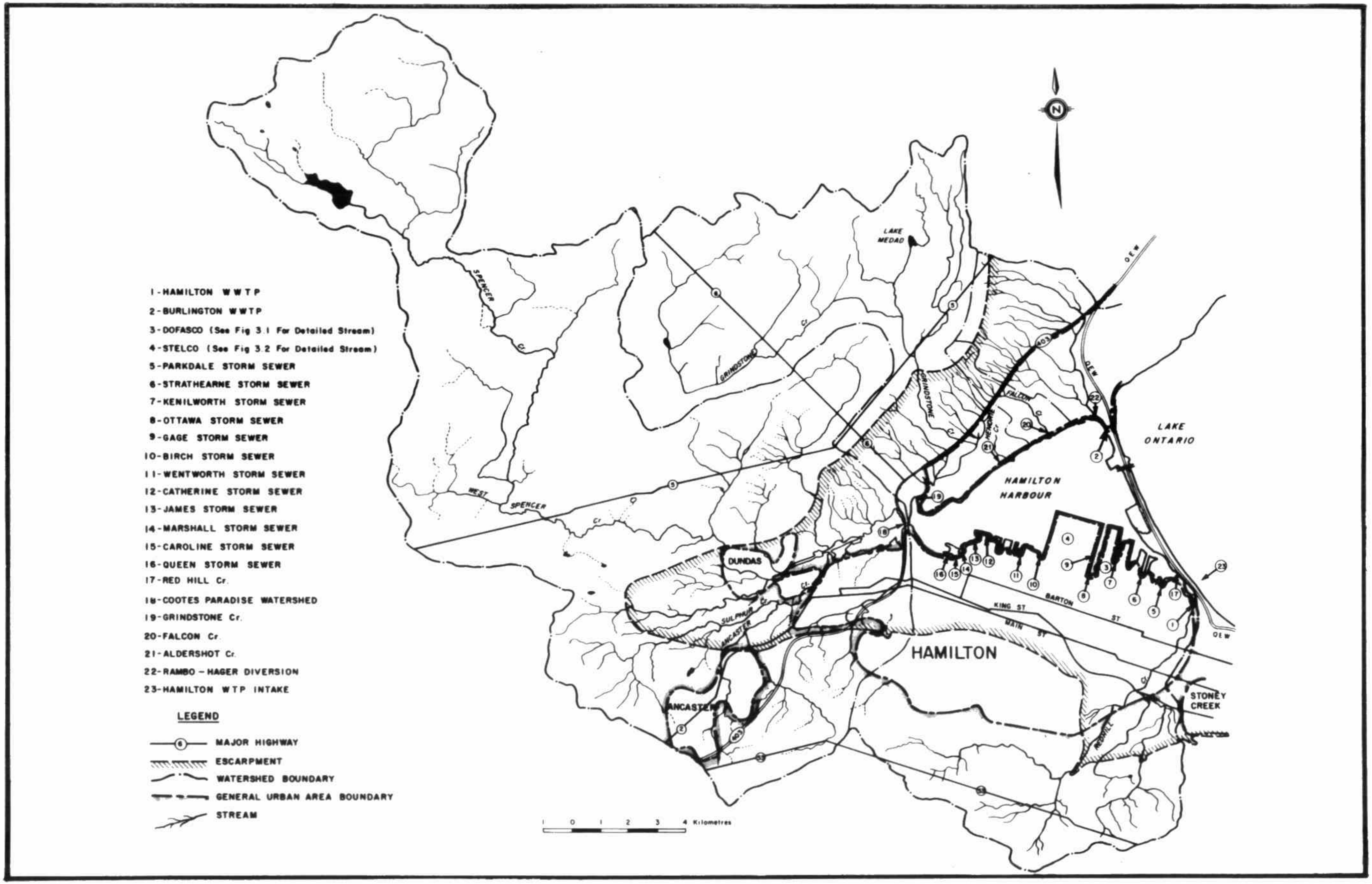

Fig. 2.1 Hamilton Harbour Watersheds

3.0 INDUSTRIAL DISCHARGES TO HAMILTON HARBOUR

3.1 INTRODUCTION

The main industrial users of water from Hamilton Harbour are the two integrated steel mills - Stelco and Dofasco - and a few minor industrial users such as Firestone. The objectives of this section are: (i) to describe the steel production processes and their water requirements in general terms and (ii) to describe the actual measurements of various water pollutants from these two steel mills which have been made during the 1970's. As the quantities of water withdrawn directy from the harbour by other industrial users are small and as measurements on these flows are sparse, these contributions are not considered.

3.2 A GENERAL CHARACTERIZATION OF WATER POLLUTANTS FROM CANADIAN STEEL MILLS

The major production operations in an integrated steel mill consist of the following: transport of raw materials to the plant site, coke making, iron manufacturing in the blast furnace, steel manufacturing, hot forming, cold rolling, and fusion of particulates in the sinter plant. Love (1975) examined these major operations and typical ranges of concentrations of the major pollutants resulting from each operation at the four major integrated steel mills in Canada. Love does not specify which values come from which mill in order to maintain the privileged character of each industry's information on their operations. Further, because they are often based on sparse data, characteristics cannot be attributed to the individual operations of either of the two mills using water from Hamilton Harbour. The four integrated mills examined by Love have the following capacities (tonnes/year) for basic pig iron and for crude steel, respectively: Sydney Steel Company - 820,000/970,000; Dofasco - 2,400,000/2,800,000; Stelco - 3,700,000/5,200,000; Algoma Steel Company - 2,400,000/2,400,000. They use, on the average, 82.3 m^3 of process water* per tonne of steel and 1.7 m^3 of potable water.

* If the water comes in contact with the coke, iron or steel, it is termed "direct process water"; if it does not make such contact, it is termed "indirect process water".

The study of Love is adapted and used to present a generalized picture of water pollution from Canadian steel mill operations; assessments concerning the adequacy of environmental control are those of the writer.

3.2.1 Transportation and Unloading

In Canada, coal and iron ore are generally shipped by water to the mill site while limestone is transported by road or rail from a local pit. The coal and iron ore are unloaded to form piles from which particles may become wind-blown and subsequently deposited either on water or on land. To prevent such removal, one common control method is to keep the piles wet with periodic hosing with water. This water plus precipitation are sources of drainage water from the piles. In most plants, incomplete provision is made for trapping drainage water in order to prevent its entry into surrounding water bodies. Drainage water from coal and coke piles at two plants have the following approximate characteristics (Love, 1975): oil - 2.5-9.5 mg/L as CCl_4 extractable, phenol - 0.2-0.5 mg/L, suspended solids - 28-9100 mg/L.

This data is based on a few spot samples and estimates of associated drainage volumes are not known. To date, control of drainage water and design and operation of storage areas has not received much attention. This information about the quality and quantity of runoff is essential for rational planning of environmental controls.

3.2.2 By-products From Coke Making

Coke- making provides suitable fuel for blast furnaces. In this process, blends of low sulphur coal are heated in a chamber from which air is excluded. Volatiles driven from the coal are recovered to make coke chemicals, coal tar and coke oven gas used for heating the coke ovens. The hot residue is quenched with water to form coke. The by-products are ammonia (formed from the gaseous reaction of hot nitrogen with hot water), ammonia compounds, and phenols. The 1974 coke production capacity of Stelco was 3,100,000 tonnes and

of Dofasco, 1,600,000 tonnes. Typically, one tonne of coke produces 55 m^3 of coke oven gas whose heating value is 20 MJ/m^3. The five main waste water streams from the process are weak ammonia liquor, coke quenching effluent, over flows from the light oil recovery washers and final coolers, and waste water from the H_2S recovery plant. Although small in volume, the weak ammonia liquor has a high pollutant concentration. The observed range (Love, 1975) for the four Canadian mills are: ammonia 3,200 - 3,500 mg/L, cyanides 26 - 38 mg/L and phenols 400 - 500 mg/L.

The weak ammonia liquor is typically treated in a secondary activated sludge plant. In a detailed 1973 study of one plant in which 520 m^3/d of weak ammonia liquor was treated by activated sludge, the following removal rates were achieved: COD-42% (14,700 to 6,700 mg/L), phenols-99.9% (400 to 0.2 mg/L), cyanides-33% (32 to 15 mg/L as CN), and thiocyanate-90% (270 to 26 mg/L as CNS), and ammonia 0% (800 mg/L in influent). The pH changed from 8.1 in the influent to 7.3 in the effluent. Before entry to the secondary plant, most of the ammonia was removed by ammonia stripping and residual tar was separated in a storage tank. The lack of ammonia removal in the plant was caused by low levels of nitrification, suggesting that the sludge age was too low. An alternative for ammonia removal is discharge to the municipal system. Phenol recovery plants are used, but have proven unable to reduce phenol concentrations to the levels mandated by effluent standards. The major problem area at present is to assure the removal of residual organics, cyanide and thiocyanate.

3.2.3 Blast Furnace and Iron Manufacturing

In the blast furnace, coke, limestone and iron ore plus hot blast gas are used to produce molten iron, slag and gases. Limestone combines with silica, the impurity in the ore, to form a low melting point slag which floats. The major water uses are cooling water and wet type scrubbers. The scrubbers clean gases, which are approximately 12% as CO_2, 27% as CO, 2% as H_2 and 59% as N_2, from the top of the blast furnace. After treatment in gravity settling tanks, the scrubber water has the following pollutant

concentrations: suspended solids - 10 to 90 mg/L, oils - 1 to 4 mg/L, phenols - 0.02 to 0.06 mg/L; cyanide - 0.03 to 7.5 mg/L and ammonia - 0.3 to 130 mg/L. The large volumes of water of low concentration make treatment costly. Recirculation, rather than once-through cooling and washing as is extensively practiced, is one significant measure which would improve the potential for control of these discharges.

3.2.4 Steel Manufacturing

The two main methods of steel manufacturing are the basic oxygen furnace (BOF) and the open-hearth furnace (OH). In 1974, 68% of Canadian production was by the former method, while 32% was by the latter and older method. The furnace in the basic oxygen process is a barrel shaped vessel from which steel and slag are removed by tilting the vessel in the appropriate direction. After the basic oxygen furnace is charged with scrap and molten iron, an oxygen lance is used to start reactions leading to iron oxide, steel of desired carbon content, slag and gases. Carbon in the molten iron, sulphur, silica and phosphorus serve as a fuel since they are burned in the oxygen. Water usage ranges from 8 to 44 m^3 per tonne of steel. In the open-hearth furnace, the basic reactions and the charging procedures are similar but the OH is heated by the convection of hot gases over the surface of the metal and by radiation from the roof of the furnace. In both methods, the major water uses are indirect cooling of equipment (e.g. heat exchangers) and gas cleaning. The cooling water is uncontaminated and is typically a once through system. The gas cleaning water has a high content of finely-divided red suspended solids of a highly variable composition. Gravity clarifiers reduce the suspended solids from the 20,000 mg/L range to the 100 - 125 mg/L range. Coagulation of the cleaning water before clarification increases the particle sizes and gives a further reduction to the 15 - 35 mg/L range.

3.2.5 Hot Forming

Hot forming consists of the compression of the hot steel ingot between surfaces of two rotating rollers. Successive rolls produce the desired thicknesses. The ingots from steel making are reheated to a uniform temperature and rolled into a slab (rectangular), a bloom (square), or a billet depending upon the desired final shape. Hot forming includes slabbing, plate, hot strip, bloom, billet, rod and bar, structural and rail mills. Water use ranges from 2.5 to 88 m^3 per tonne. Water is used for indirect cooling and direct process water. Cooling water, which is once-through, has no contaminants and a small change in temperature. Direct process water is used for scale removal and transport and roll cooling. Scale is the surficial material that is oxidized during heating and hot rolling. The waste water has light and heavy suspended solids (2,000 - 3,000 mg/L), and both floating and emulsified oils (75 - 125 mg/L). Scale pits are used to recycle scale to the sinter plant. Settling basins and/or deep-bed sand filters are used to reduce the effluent to 5 - 50 mg/L of suspended solids and 5 - 10 mg/L of total oil. Typically, settling basins cannot consistently provide adequate treatment and must be replaced by sand filters (either gravity or pressure).

3.2.6 Cold Finishing

Cold finishing imparts a desired surface, shape or mechanical character to hot metal products. Cold finishing includes pickling, cold rolling, tin plating, and continuous galvanizing. Pickling removes any surface impurities (FeO, Fe_2O_3, Fe_3O_4) by hydrochloric acid and inhibitors. The hydrochloric acid is regenerated for reuse. Cold rolling reduces the unheated sheet or coil thickness by rolling; 2.3 to 27 m^3 of water are used per tonne. Tin plating is a continuous electrolytic process. Baths for cleaning, rinsing and quenching require high quality water.

- No specific data for pollutants for cold finishing operations were found by Love (1975). In general, the principal waste waters are waste pickle liquor, concentrated bath solutions, rinse waters and

effluents containing various trace metals (tin, zinc, chromium, cadmium, nickel), cyanide, phenols, acids, alkalies, and detergents. Tallows, mineral and vegetable oils and detergents are added to water to give rolling solutions specific lubricating and mechanical properties. The solution is continuously reused in newer mills until contamination with metal soaps and iron fines necessitates replacement by fresh solution. This direct cooling and rolling waste water requires treatment.

3.2.7 Sinter Plant

The sinter plant uses coke breeze and metallurgical fines from various operations and fuses them into coarser material suitable for charging a blast furnace. Water pollution is low; the main source of pollutants is the dust collecting system.

3.3 THE QUALITY OF WASTE WATER DISCHARGES FROM INDUSTRIES TO HAMILTON HARBOUR

Water quality data for various pollutants measured between 1971 and 1977 by Stelco at twelve intake and discharge streams of the Hilton Works and by Dofasco at five intake and discharge streams are shown in Appendix A.3. Loadings, calculated by multiplying the average annual concentrations in 1977 by the total estimated annual flows, are shown in Table 6.1 for each stream.

3.3.1 Description of Waste Discharges for Dofasco and Stelco.

3.3.1 a) Dofasco

There are four major discharges - boiler house, lagoon overflow, Ottawa Street and coke plant - and one intake at Dofasco. A sketch of the various process streams contributing to each discharge is shown in figure 3.1. The flow rates of discharges (Table 3.1) were measured approximately once a year between 1971 and 1977. The intake flow has not been measured and is estimated. The difference between intake flow - 8.9 m^3/s (169 MIGD)[1] - and the sum of discharge flows - 8.8 m^3/s (167 MIGD) - is composed of small unmonitored discharges and evaporation from cooling water in various processes.

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[1] MIGD = million imperial gallons/day.

The lagoon overflow, coke plant and boiler house discharges serve the primary production processes of coke through steel making. The hot and cold rolling processes discharge to the Ottawa Street outfall.

The boiler house discharge consists of indirect cooling water plus blow down and condensation water. The boiler house has eight steam generation units feeding steam to turbo blowers pressurizing the blast furnaces. The steam is produced from softened Hamilton Harbour water and the backwash from the zeolite softening is discharged to the harbour. The coke plant and meltshop sewer discharges non-contact cooling water from the oxygen plant, the lance cooling in the basic oxygen furnace, the quench station and the cyanide process blow down.

The lagoon, receiving waste water from the blast furnace thickener, the basic oxygen furnace thickener and the biological waste water treatment plant discharged from 1971 to 1977 to the lagoon overflow, presently known as the Ottawa west-side sewer. After the small blast furnace thickener was replaced by a larger one in 1977 and the basic oxygen furnace thickener was completed in January 1978, the lagoon was filled to provide land for plant expansion. Subsequently the blast furnace, basic oxygen furnace and waste water treatment plant discharges were rerouted around the lagoon area. The suspended solids levels from the thickeners are presently the same as from the earlier lagoon discharges. The waste water treatment plant, the two clarifers (with polymer addition) and miscellaneous cooling tower blowdowns make up the 3.9 m^3/s (75 MIGD) in the lagoon overflow.

In coke making, 14.5 tonnes of coal produce 10 tonnes of coke and 4.5 tonnes of gas from volatilization and quenching of the hot cokes. The gas, composed of hydrogen sulphide, hydrogen cyanide, ammonia, gas tars, phenols and light oils such as benzene and toluene, is used to make various by-products and to produce energy for the hot rolling heating pits. Quenching operations use 0.31 m^3/s (5.8 MIGD) from recycled water from previous quenching and from harbour make-up water. An excess of 0.02 m^3/s (0.3 MIGD) is produced from condensation.

A waste water stream 0.013 m^3/s (0.24 MGD) flows to an ammonia still from by-products production (400 mg/L ammonia in influent, 100 mg/L in effluent except for periodic upsets) and then to the waste water treatment plant (MLSS-mixed liquor suspended solids - of 10,000 mg/L in the aeration tank, secondary activated sludge age of 50 days, 50% volatile sludge). The plant, whose influent is augmented by other streams to 0.2 m^3s (0.4 MIGD), achieves 99% phenol removal (influent approximately 300-400 mg/L), approximately 50% thiocyanate removal (influent approximately 5-10 mg/L), but no ammonia removal.

A 1.5 m^3/s (29 MIGD) stream of once-through scrubber water from the blast furnace contains particulates which are removed in the blast furnace thickener. These particles are particularly difficult to remove during cold weather because of the wide range of particle zeta potentials. A 0.9 m^3/s (17 MIGD) stream from the basic oxygen furnace contains the particulates and gases scrubbed from hot metal charging and blowing emisions. The BOF reduces carbon in steel from 2% to approximately 0.2%. Consistent particle removal is achieved in the BOF thickener.

The Ottawa Street discharge receives waste water from the hot mill filtration plant, the hydrochloric acid regeneration plant, and the cold finishing waste water treatment plant, all three of which are located 30 feet high over Ottawa Street North. The filtration plant and acid regeneration plant were built in 1972, the cold mill waste water treatment plant in 1974. The hot mill filtration plant treats the majority of water from the scale pits in the hot rolling mill. Since the influent averages 250 mg/L suspended solids, filter runs are short, averaging two hours. The effluent of 1.5 m^3/s averages 200-300 mg/L dissolved solids and 30 mg/L suspended solids. An additional 0.4 m^3/s (8 MIGD) from the scale pits is discharged directly to the sewer as the filters do not have sufficient capacity.

The hydrochloric acid regeneration plant discharges 0.8 m^3/s (1.6 MIGD) after regenerating a 0.004 m^3/s (0.07 MIGD) pickle liquor stream (100 g/L iron, 30 g/L HCl) using a fluidized bed. The cold mill waste water treatment plant treats three wastes: oil emulsion from detergent tanks (0.012 m^3/s, 0.22 MIGD) in a batch operation, acid and alkaline rinses (0.12 m^3/s, 2.3 MIGD) and chrome rinses containing 1,000-2,000 mg/L chromium from tin plating operations. From the cold mill waste water treatment plant, 0.074 m^3/s (1.4 MIGD) is discharged to the sanitary sewer, the remainder to the storm sewer.

3.3.1 b) Stelco

For Stelco there are two major intakes - #1 BSPH (Bay Shore Pump House) averaging 20% of total inflow, and #2 BSPH and five major discharges - east side lagoon combined, north outfall, #3 open hearth cooling (No. 3 O.H), north trunk and west side open cut (WSOC) - to Hamilton Harbour. A sketch map of the various waste streams is shown in figure 3.2. The other discharges described in table 6.1 represent other major streams, some of which discharged previously directly to the harbour but which now join one of the five major discharges. Flows for the various process streams in 1971-1976 are shown in table 3.2 and the average daily intake for the period 1971-1977 is shown in Table 3.3a. Table 3.3b gives the average flow on a monthly basis for 1977. A complete water balance for 1977 is shown in table 3.4. During this period, steel production increased while water consumption remained essentially constant, suggesting that water conservation and recycling has been employed successfully. Both Stelco intakes are metered. The flow estimates for the various discharges are based upon measurements made during 1975- 1977. The 0.5% difference between intake and discharge can be attributed to evaporation and measurement error (Table 3.4).

The intake for #1 BSPH is located at the north-east corner of #3 dock (see figure 3.2) and for #2 BSPH at the south-west corner of the Hilton works property. As both intakes are located adjacent to the major discharges (#1 BSPH near the open hearth-basic oxygen furnace and the north outfall and #2 BSPH near the west side open cut), partial recycling of waste water is likely.

The west side open cut (2.5 m^3/s, 48 MIGD) and the north west outfall (north trunk, 3.2 m^3/s, 60 MIGD) drain the coke making, blast furnace and by-product operations located beside the #2 ore dock. The west side open cut drains seven main sources:

1. Indirect cooling and process water from #3, 4 and 5 coke batteries and indirect cooling water from #1 by-products plant.
2. Indirect cooling water and stove stack direct cooling water containing phenols, cyanides, and particulates from B, C, and D blast furnaces.
3. Fractional overflow (0.007 m^3/s, 0.14 MIGD) from the breeze basins, (condensation from the stream receiving wastewater from the sump and breeze basin, of the light oil plant and from the coke oven quench causes the excess).
4. Indirect cooling and ground water infiltration from the stack sumps in the oil plant.
5. Effluent from clarifiers in which iron, coke and dolomite fines are settled.
6. Central boiler house discharges.
7. Occasional blow down from the final cooler.

An additional stream from International Harvester (0.02 m^3/s, 0.4 MIGD) and some surface drainage from #2 ore dock also join the west side open cut. Ammonia absorber water from the #1 by-products plant goes to the #2 by-products plant. Zeolite blowdown and lime softening sludges from the boiler system pass through the clarifier for particulate removal before discharge. The boiler system adds some particulates and dissolved solids, mostly chlorides. Construction for recirculation of the clarifier effluent is in progress.

Of the west side open cut discharges in 1977, 70% was from indirect cooling and 30% from direct process water.

A sketch of the by-products area is shown in figure 3.3. Both #1 and #2 by-products plants are, with four major exceptions, the same. First, there is only one ammonia recovery plant located in the #2 area, into which the stream from the ammonia absorber in #1

flows. Second, there is an evaporative cooling unit in #2 which generally uses only once-pass water due to maintenance problems. Indirect cooling water is used to cool the final cooler, necessitating occasional blow down from it. Third, weak ammonia liquor from #1 is discharged to the sanitary sewer but in #2 it is recycled. Fourth, blow down from the ammonia recovery plant (0.003 m^3/s, 0.05 MIGD) is discharged to the north-west outfall. The primary liquor cooling loop and the light oil plant use indirect cooling water.

Excess condensate from the primary liquor loop in by-products plant #1 contains cyanides and phenols in addition to ammonia. From 1971 to 1973, the weak ammonia liquor (WAL) stream in by-products plant #1 was discharged directly to the west side open cut. In 1973, it was diverted to the sanitary sewer system after appropriate permits were granted by the City of Hamilton, since bio-treatability studies indicated that the WAL stream had no detrimental effects on the performance of the Hamilton WWTP. Biological oxidation of phenols and cyanides can occur in the sewer system and in the waste water treatment plant.

The north west outfall drains six sources: (1) #6 and #7 coke oven battery, (2) the E blast furnace, (3) #2 by-products plant, (4) sinter plant, (5) ammonia recovery plant, (6) the clarifiers. The E blast furnace is on about 50% recirculation with 0.13 m^3/s (2.5 MIGD) returned from the gravity clarifiers. In the north west outfall, 92% of the discharge is indirect cooling water and 8% contact cooling water.

The #3 open hearth-basic oxygen furnace outfall (OH-BOF, 2.7 m^3/s, 52 MIGD) and the north outfall (0.84 m^3/s, 16 MIGD) discharge on the north side of the Hilton works. OH-BOF outfall contains only indirect cooling water with 90-95% being used in the open-hearth. The only water use in the basin oxygen furnace is for the cooling of the oxygen lance. The north outfall drains three processes: froth floation discharge from the oil treatment plant (15% of discharge), filter plant effluent which treats scale pit overflow from #3 bloom and billet (65% of discharge) and furnace cooling from the 148 inch plate mill (20% of the discharge).

The east side outfall (5.2 m^3/s, 99 MIGD) receives water from two sources: the east side lagoon filtration plant and the east side lagoon. Prior to December 1975, only the east side lagoon discharge was sampled. At that time the filtration plant commenced operation and a new sampling point (the east side combined) was established downstream and includes the lagoon, the filtration plant and the city storm sewer (Gage Street) discharges.

The east side outfall receives both process and cooling water from the hot forming and cold mill operations. As the maze of lines flow from many buildings, separation of the two streams is difficult and Stelco presently plans to treat all waters on the east side in the filter plant, except for the city storm sewer discharges. Hence, the amount of water used in direct process and indirect cooling are unavailable. Similarily, the use of water in hot forming and cold rolling are unknown. While a good assessment could probably be made by examining accounting records, a reasonable estimate is that 80% of the east side outfall discharge is from hot forming operations while 20% is from cold rolling operations.

Two major streams drain into the east side lagoon. One stream drains the scale pits from the hot forming operations and the #3 open hearth. It also drained the #2 open hearth, which has been closed down for a few years. The hot forming operations include the #1 bloom and billet mill, the #1 rod and bar mill, the 12" x 10" mill, the hot strip finishing mill, the universal slaving mill, and the 148-inch plate mill. The second stream drains various direct and indirect cold mill operations as well as the hot strip mill. Included are three pickling lines, three galvanizing lines and three tinning lines. In the general cold mill sequence of hot strip milling followed by pickling, cold rolling and then either galvanizing or tinning, the waste water streams are respectively contaminated with particulates, iron and acid and heavy metals. Regeneration recovers much of the hydrochloric acid from the pickle stream. The ion exchange plant recovers much of the chromium and the phenol evaporator concentrates phenols from the tinning lines for subsequent discharge to the sanitary sewers.

The #1 cell of the lagoon provides for settling of coarse particles. Scale is raked off the clay bottom by auger and cycloned. The cyclone underflow is clarified in the sinter plant while the overflow is thickened and magnetically separated. From the #1 cell, as much water as possible (currently one-half of the flow) is filtered by the east side lagoon filtration plant. The total flow will be filtered upon the completion of the plant expansion. The remaining flow passes into #2 lagoon cell and over a weir into the east side outfall.

The city storm sewer, which forms a third stream discharging into the east side outfall, receives discharges from the 60-inch cold mill sewer (0.69 m^3/s, 13 MIGD) a heavy gauge shear line (0.015 m^3/s, 0.29 MIGD) and combined storm-sanitary sewer overflows from the industrialized urban area between Burlington Street and the escarpment. The cold mill water includes process water from annealing (batch), a pickle line and scrubber water from hydrochloric acid regeneration and indirect cooling water from the ion exchange plant. The water from the heavy gauge line is mainly from contact cooling.

The main pollutants in the east side outfall are particulates, heavy metals and some oils and greases. The question arises whether the measured pollutant concentrations are from Stelco discharges or from storm water runoff. While a large fraction of oils would be treated in the oil recovery plant and in the filtration plant, significant discharges are expected. Additional solids and total organic carbon would be added by storm water overflows. It is unlikely that storm events (1 - 2 hours) are sampled during the bi-weekly to monthly sampling program of Stelco due to the short duration of storms and due to the improbability of a person sampling during a rain. It is therefore probable that the samples from the east side combined outfall represent essentially Stelco discharges.

Four other Stelco discharges warrant attention. The hot strip finishing uses 0.015 m^3/s (0.29 MIGD) of city water for pickle line scrubbing before discharge. The #2 rod mill at Strathearne Street uses 0.53 m^3/s (10 MGD), pumped by the municipal pump house for direct contact cooling of rods. The scale pit overflow passes through a lagoon before discharging to the harbour. The 28-inch mill at the Ontario works at the foot of Queen Street uses harbour water (0.063 m^3s, 1.2 MIGD) for rail making. Its discharged water will contain some particulates and oil from scale pits. The Parkdale works (0.04 m^3/s, 0.8 MIGD) is a finishing operation; its cleaning lines discharge to a lagoon and then to the harbour, while its galvanizing lines containing zinc and oils are neutralized before discharge to the sanitary sewer. Sparse or no measurements of contaminants have been made on these four discharges.

Stelco discharges approximately 0.068 m^3/s (1.3 MIGD) to the city sewer system at three points: 0.045 (0.85 MIGD) at Depew and Burlington Streets and 0.021 (0.4 MIGD) and 0.003 (0.05 MIGD) from the east side of the plant at two neighbouring easterly locations. Municipal permits determine the strength and quantity of the waste water. The Depew Street point represents the largest loading as it not only has the largest flow, but has also received the diverted flow of the weak ammonia liquor containing high concentrations of ammonia, phenols, and cyanide since 1974.

3.3.2 Water Quality of the Dofasco and Stelco Intakes and Discharges

3.3.2 a) Measurements Made by the Industries

For the period 1971-1977, Dofasco has comprehensive measurements at all intakes and discharges for ammonia, suspended solids, iron, ether solubles, cyanides and phenols. For the corresponding period, Stelco measured iron, ether solubles and cyanide on all intakes and discharges, but phenols, ammonia and COD were measured only at the two intakes and at the west side open cut.

Since ammonia concentrations in the intakes are constant for the period 1971-1977 (Appendix A-3), the harbour concentration of ammonia has not changed materially. All ammonia discharge data for Dofasco are constant, showing that any in-house treatment modifications have not improved the discharge quality significantly. The west side open cut of Stelco showed a significant decrease between 1972 and 1974, reflecting the diversion of the weak ammonia liquor stream from the west side open cut to the sanitary sewer system. Significantly, there is a modest decrease in ammonia levels in the #2 BSPH intake during the same time period. Since there is a fair degree of short-circuiting from the west side open cut to the #2 BSPH, this decrease reflects the decrease in the west side open cut levels and suggests that the harbour on the average dilutes the west side open cut discharge about five-fold in the distance between this discharge and the intake.

No significant increase or decrease is apparent in suspended solids and COD. There is a small decrease in iron levels in the northwest outfall (Stelco). The Ottawa Street discharge has high iron concentrations, otherwise the concentrations are approximately constant from 1971 to 1977. There is a significant decrease in the Ottawa Street discharge of ether solubles at the end of 1975 reflecting the effects of the start-up of Dofasco's waste water handling system on that discharge stream. Ether soluble levels in other streams are approximately constant.

The west side open cut showed a significant four-fold decrease in cyanides between 1972 and 1974, caused by the relocation of the weak ammonia liquor discharge. Other Stelco streams are approximately constant except for the #2 BSPH intake whose decline mirrors the west side open cut decrease. All Dofasco intakes and discharges show a signficant four-to-ten-fold decline in cyanides between 1971 and 1977. A decrease in the intake levels obviously reflect the generally lower levels discharged. The significant improvement at Ottawa Street is probably due to the waste-water treatment plants, but improvements at other points must be due to significant improvements in waste water handling, such as sewer separation and subsequent treatment. Cyanide levels in Stelco intakes and all

discharges except for the west side open cut and northwest outfall are of the same order as Dofasco discharges. Hence separation of the appropriate streams and subsequent discharges to the sanitary sewer or insitu treatment should significantly increase the quality of Stelco discharges along the #2 ore dock. Separation of the streams from the coke making-blast furnace operations should provide this improvement.

No significant change in discharge concentrations of phenols is apparent from 1971-77 except at Dofasco's Ottawa Street and coke plant outfalls. The improvement at Ottawa Street occurred around 1975 - 1976, while at the coke plant the improvement has been steady from 1971 - 1977.

3.3.2 b) Measurements Made by Environmental Agencies

Concentrations measured from 1971-1977 by the Industrial Wastes Section, Ministry of the Environment, are shown in Appendix A.3 to "fill in holes where industrial measurements are not available." The associated gross and net loadings are shown in Tables 3.5a, 3.5b, 3.6a and 3.6b for all parameters measured. Overall, the gross loadings show fairly good consistency from year to year, since approximately the same volumes of waters were used each year. Except for the removal of ammonia streams from discharges, the chemical character of the major streams has not changed significantly.

Several problems, however, exist with these data. They represent eight samplings over a six year period. A few other surveys were made during this period but are unavailable at the time of this writing. In addition, sampling and analytical errors and daily variations of unknown magnitude in many of these parameters make it difficult to infer precise estimates of loading for any one year or of a trend in loadings over this period. A much better estimate of loadings can be made using the more comprehensive data set of Stelco or Dofasco for the limited number of parameters and discharge streams sampled. As the magnitude of inter-laboratory errors is unknown, visual inspection to ensure that both sets of numbers are in the same ball park is the most appropriate quality control check.

For several specific parameters, the net loading values show variations of one to two orders of magnitude between the years. For example, net discharges from Stelco for COD, total phosphorus, ammonia and total dissolved solids have large extremes, whereas, overall, the net loadings for Dofasco are much more constant. For all of April 1972, the net Stelco estimates are too close to the gross estimates.

Total dissolved solids should have significant positive values. Total dissolved solids represent the difference between two weights, after drying to constant weight and the error associated with a TDS value is the non linear sum of the individual errors.

Similarily the error associated with a value for net input is the non linear sum of the individual errors of gross intake and gross discharge of TDS. Thus, the error associated with the estimation of the net input of total dissolved solids is the sum of the errors in the individual original weights.

Estimates of gross loading of Kjeldahl nitrogen and ammonia for Dofasco during April 1973, appear low, causing a low estimate of net discharge. Estimates of net loadings for chloride and zinc for November 1971 also appear to be low. The lowest report value of COD during this period was 30 mg/L.

Environment Canada is in the middle of an intensive measurement program on all streams within both Stelco and Dofasco. The objective of this program is to derive estimates of pollutant discharges from each operation within an integrated steel industry. Measurements on the Stelco west side discharge and on intakes were taken during the summer of 1978, and at Dofasco during the fall and winter of 1978-1979. In the summer of 1979, measurements were also made on the east side of Stelco. Data from the last two time periods is not available at the time of writing. The data from the summer of 1978 for Stelco is included here to augment the data base for 1977. Present data for 1971-1977 suggest that there have not been significant changes in either water flow or chemical quality. Accordingly, the 1978-79 data may be treated as representative of the 1977 time period.

The data - gross and net concentrations and loading estimates - are shown in Table 3.7 for 20 parameters in the west side open cut, north- west outfall, #3 open hearth and the light oil plant. Daily net concentrations are calculated by subtracting the weighted mean intake concentration from the observed discharge concentration. Multiplying the difference by the daily flow gives the daily load. When the intake concentration is higher than the observed discharge concentration, the net concentration of that day is given a value of zero.

Inspection of the net concentration values for all parameters and all discharges shows that there is a zero value in almost all data sets. Attributing a zero net value for any material is reasonable if no material is added to the process stream. Only five parameters at the west side open cut - chloride, sulphate, fluoride, zinc and manganese - and four parameters at the north west outfall - cyanides, chlorides, sulphate and fluoride - have a range of standard deviations of the mean which does not include zero. If the data are normally distributed, only 68% of the observations are within one standard deviation of the mean. The inclusion of zero within one standard deviation is a first requisite for suspecting that the mean is not significantly different from zero in the statistical sense. For such paramaters there is no statistically measurable addition of material to any of the streams. But if the values of net loading for a parameter do not fit a normal distribution, (for example, if the lower values are bounded by zero but with no upper limit), then one cannot use the inclusion of zero in the range of the standard deviation as a method of determining whether or not significant addition of material to a stream has occurred.

A dissolved solids (TDS) budget in which one has much confidence provides a useful tool for assessing harbour-lake exhange flows. Such a budget has been employed previously (Kohli, 1977) for this purpose. As the industrial loadings are a large fraction of the input, estimates of TDS in streams measured by Environment Canada would provide confidence in this budget. Since this parameter has a large error associated with it and as a relationship between TDS and chlorides is expected, the existence of such relationships was examined. The precision on chlorides should be $\pm$ 5% . A plot of the raw data of total dissolved solids against chloride concentrations is shown in Figure 3.4a for the Stelco intakes (BSPH #1 and BSPH #2) and Figure 3.4b for the west side open cut. Data for the other discharges shows similar behaviour. The observed total dissolved solids for the intakes varies from 0 mg/L to 500 mg/L. The total dissolved solids in Hamilton Harbour are rarely below 200 mg/L except perhaps under conditions of lake water intrusion. No significant relationship is found for either intake

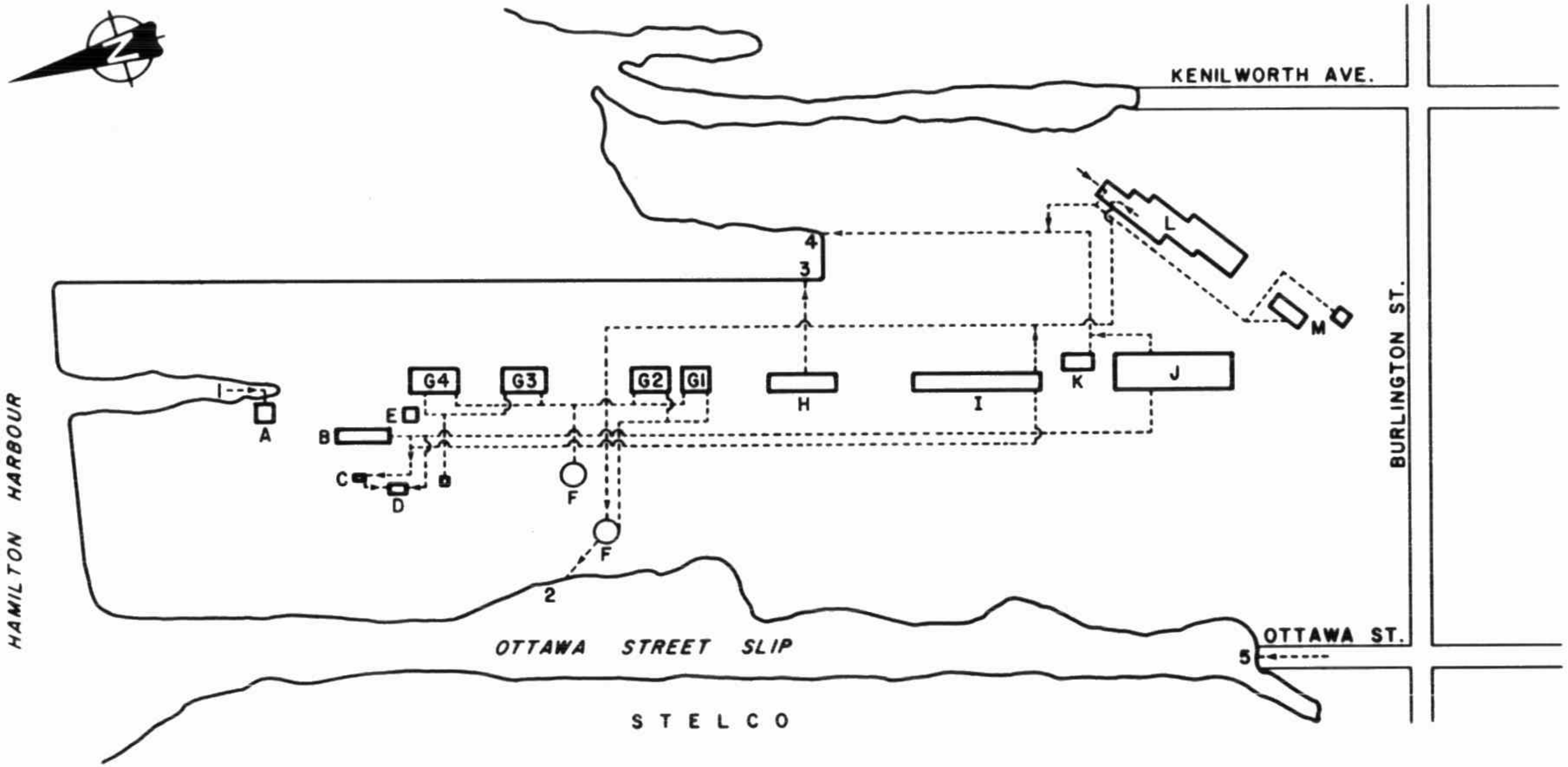
(Figure 3.4a) or in the west side open cut (Figure 3.4b). (Note that below the indicated line, 220 mg/L of total dissolved solids, the net values for the five points were zero or negative and were accordingly treated as zero by Environment Canada). But one of the most significant additions of dissolved solids to the west side open cut are chlorides from the regeneration of ion exchange, zeolite softening and boiler blow down (A. Schultz, Stelco, personal communication). Accordingly, the basic total dissolved solids data is suspect as the same analytical errors which cause values to be too low can likewise cause some values to be too high.

Examining the chloride data, the mean concentration and standard deviation in mg/L are respectively, 63.1 (S=5.5) in the intakes, 83 (S=11) in the west side open cut, 70.1 (S=7.6) in the north west outfall and 64.5 (S=4.2) in the #3 open hearth. The differences between intake concentrations and those of the west side open cut and between intake concentrations and those of the north west outfall are statistically significant at the 5% level. In fact, the small concentration difference between the intake and the northwest outfall is extremely significant (0.5% level). This does not hold for the #3 open hearth. Thus the additions of chlorides to the west side open cut, described above, are quite high. Although smaller, the additions to the north west outfall, which include some quenching and other minor operations, are still significant. The lack of significant addition to #3 open hearth outfall reflect the water usage which is essentially indirect cooling for the blast furnaces. It is concluded that, while the net loadings for total dissolved solids maybe in the right ball park, the obvious errors associated with these measurements make their use in a total solids budget for Hamilton Harbour dubious. However, except for total dissolved solids, Environment Canada estimates of loadings are considered to be good estimates.

Estimates of industrial and other loadings made in 1975 by the Lake Systems Unit of the Ministry of the Environment, are shown in Table 3.8a and those to the Ottawa Street slip in Table 3.8b. Inputs from the Ottawa Street slip to the harbour were calculated for October

1976 from current velocities measured by drogues and from chemistry data. The chemical measurements were made at seven time intervals at the surface and at 2.5 m. The warm layer, which was 1.5 m deep, was used as the slip depth to which inputs of industrial/stormwater outfalls accumulated. The measured velocites varied from 12.5 $\pm$ 2.1 cm/s (west side) to 9.8 $\pm$ 3.0 cm/s (middle) to 7.6 $\pm$ 2.7 cm/s (east side). The loading estimates (see Table 3.86) are much smaller than corresponding estimates of inputs to the Ottawa Street slip (see Table 3.8b). Whether this is due to the too small depth of water used for calculation purposes, or whether a large fraction of inputs settle out before the point of measurement is unknown.

The estimates of industrial loadings described above have varying degrees of reliability associated with them. A comparison of these estimates is presented and selection of the most appropriate estimate is made in Section 6.



LEGEND

A – PUMP HOUSE
B – COKE OVEN BATTERY
C – AMMONIA STILL
D – BIOLOGICAL TREATMENT PLANT
E – QUENCH STATION
F – WASTE WATER THICKENER
G – (1,2,3,4) BLAST FURNACES
H – BOILER HOUSE
I – COKE OVEN BATTERY
J – BY-PRODUCTS AREA
K – QUENCH STATION
L – MELT SHOP
M – OXYGEN PLANTS

WATER STREAMS

1 – BAY WATER INTAKE
2 – OTTAWA ST. WEST SIDE SEWER
3 – BOILER HOUSE SEWER
4 – COKE PLANT/MELT SHOP SEWER
5 – OTTAWA STREET SEWER

FIGURE 3.1 – WASTE PROCESS STREAMS OF DOFASCO

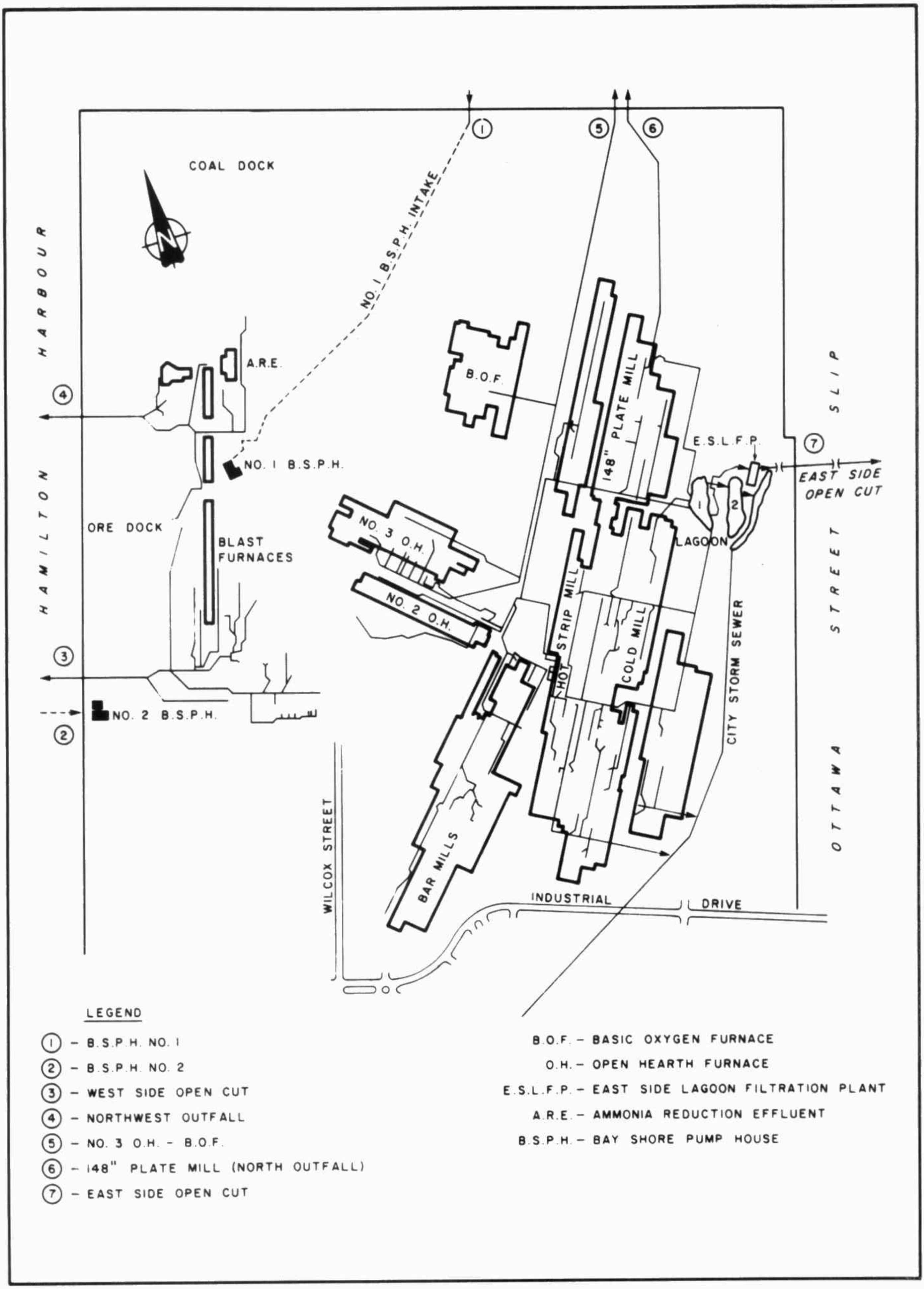
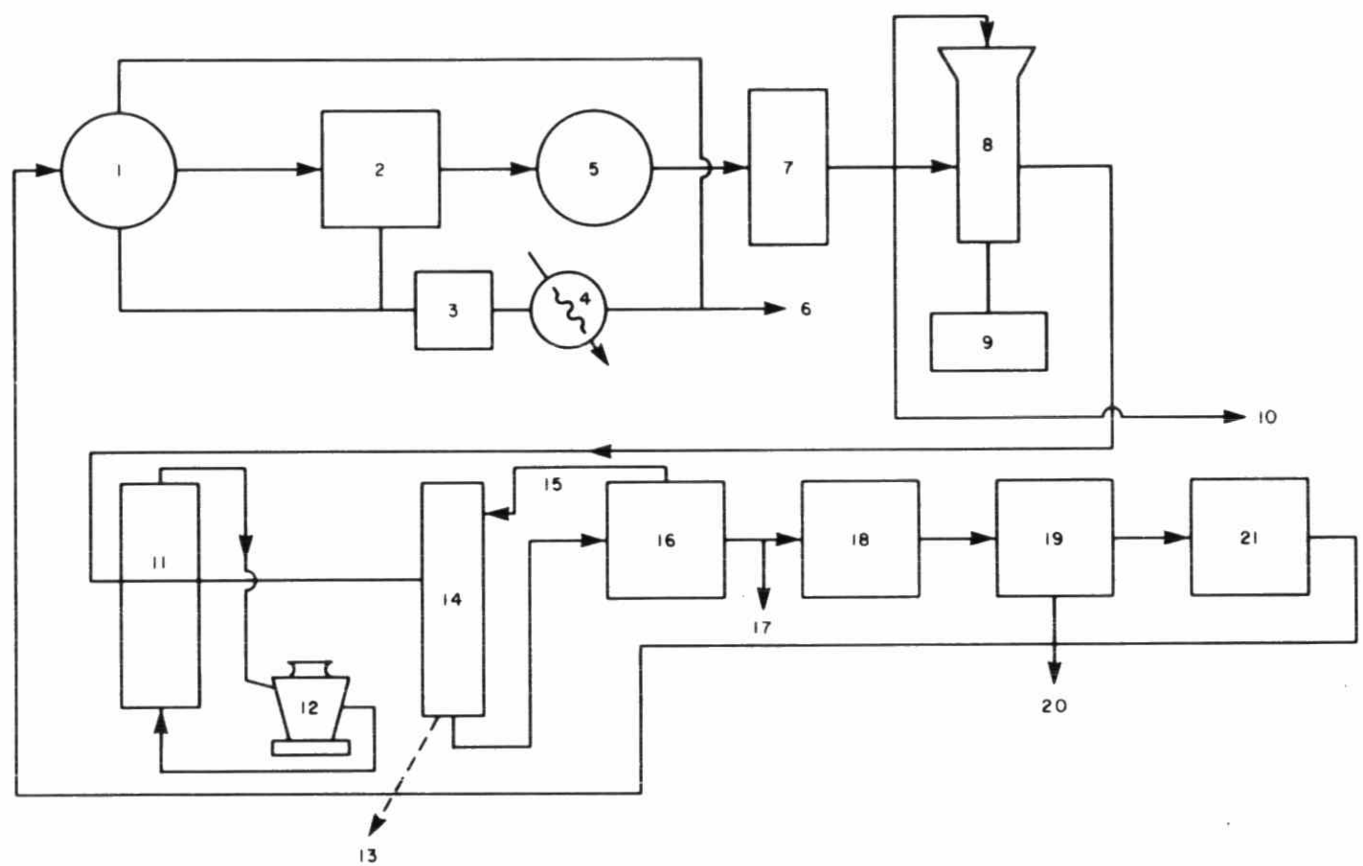


FIGURE 3.2 - MAJOR WATER STREAMS OF STELCO



LEGEND

1 – COLLECTION MAIN
2 – PRIMARY LIQUOR COOLER
3 – TAR DECANTER
4 – HEAT EXCHANGER (INDIRECT)
5 – GAS EXHAUSTER
6 – WEAK AMMONIA LIQUOR (WAL) (SANITARY, 4-5000 mg/l AS NH_3)
7 – TAR PRECIPITATOR
8 – NH_3 ABSORBER
9 – A.R.E. PLANT
10 – FRACTIONATOR BOTTOMS (NWO)
11 – FINAL COOLER
12 – EVAPORATOR COOLER
13 – BENZENE, TOLUENE, XYLENE (BTX)
14 – LIGHT OIL SCRUBBER
15 – WASH OIL
16 – LIGHT OIL PLANT
17 – CONDENSATION
18 – INTERNAL SUMP
19 – BREEZE BASIN
20 – OVERFLOW TO HARBOR
21 – QUENCH COKE OVEN

FIGURE 3.3 – STELCO BY-PRODUCTS AREA

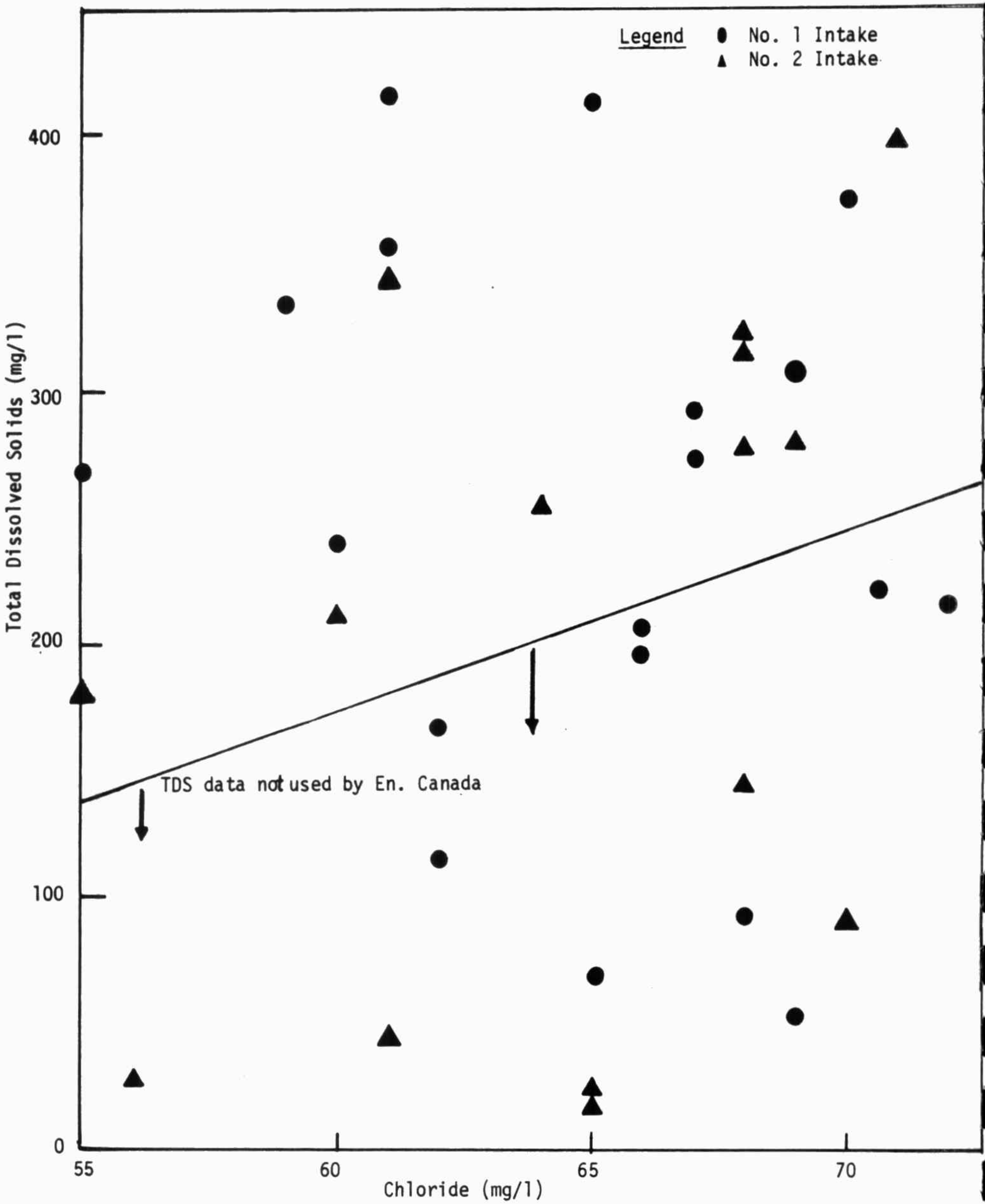


FIGURE 3.4 (a) TDS VS Cl IN STELCO INTAKES

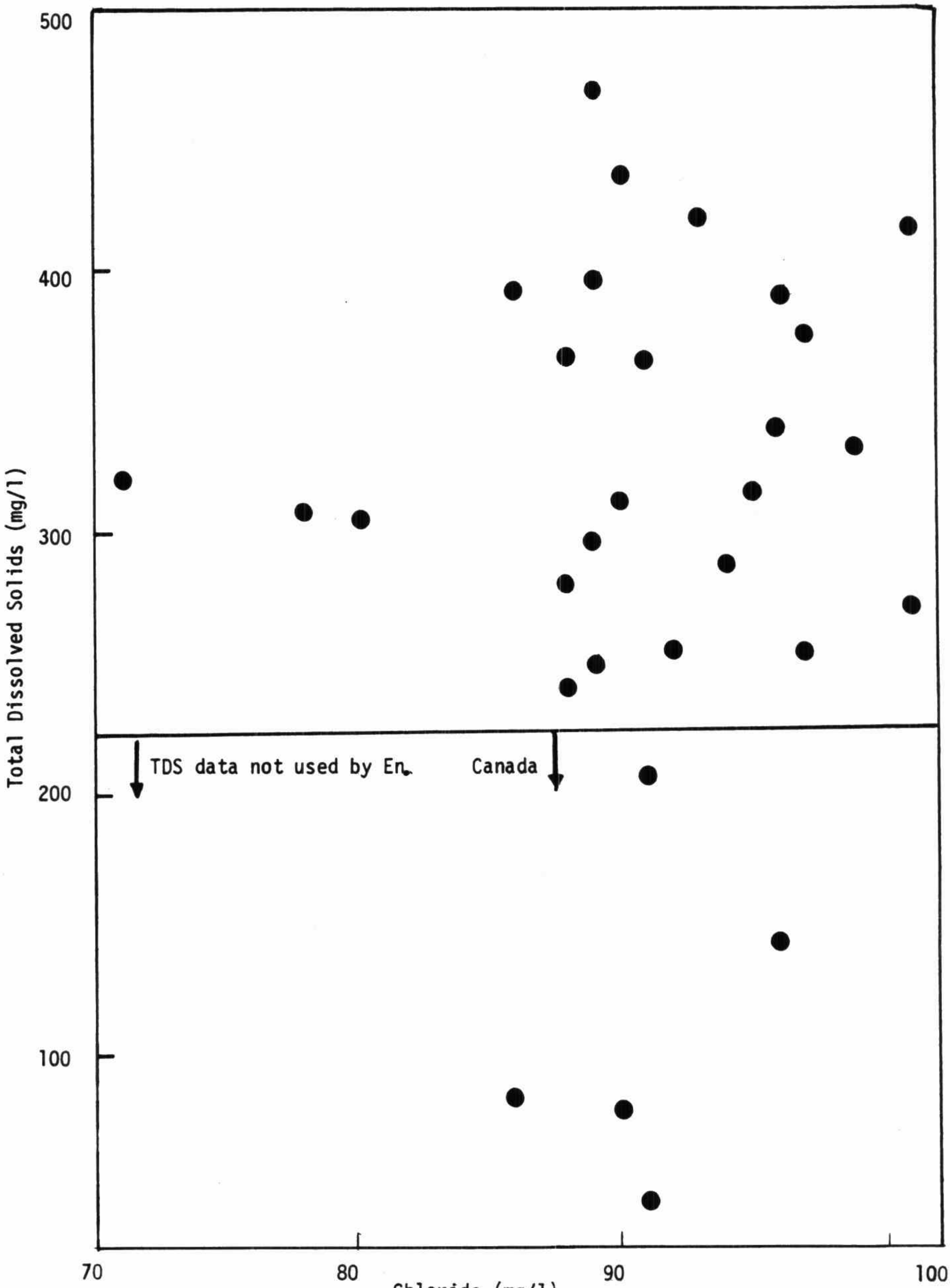


FIGURE 3.4(b) TDS VS Cl IN WSOC

TABLE 3.1

FLOW RATES FROM DOFASCO PROCESS STREAMS 1971-1976 (MIGD)

	Nov. 1971	June 1972	Sept. 1972	Jan. 1973	April 1973	June 1973	Aug. 1975	April 1976
Ottawa St.	--	--	--	46	--	--	--	--
Coke Ovens	--	--	--	28.8	--	--	16.5	--
Boiler House	--	--	--	30	--	--	--	--
Lagoon	--	--	--	76.3	--	--	74.8	--
Intake	--	--	--	173	--	--	169	--

1 MIGD = $5.26\ 10^{-2}\ m^3/s$

TABLE 3.2

FLOW RATES FROM STELCO PROCESS STREAMS 1971-1976 (MIGD)

	Nov. 1971	April 1972	May 1972	Jan. 1973	April 1973	June 1974	April 1976
WSOC	54	54	54	54	54	54	43
North Trunk	54.6	54.6	54.6	54.6	54.6	54.6	58
148 In Plate	10.8	10.92	10.92	10.9	10.9	10.9	16
East Side Lagoon	89.6	84.2	84.2	90.4	90.4	91.7	99
Hot Strip Finishing	0.36	0.36	0.36	0.36	0.36	0.36	--
No. 3 O.H.	46.7	46.7	46.7	46.7	--	46.7	46
Cold Mill/ Hot Strip	0.18	5.676	0.2	5.67	5.67	5.67	--
Heavy Gauge Shears	0.006	0.2	0.2	0.2	0.2	0.2	--
Total Intake	260.9	256.5	256.5	262.7	262.7	264	262

TABLE 3.3a

AVERAGE DAILY BAYWATER FLOW FOR #1 AND #2 PUMPHOUSES FOR STELCO 1971-1977

YEAR	#1 PUMPHOUSE FLOW (MIGD)	#2 PUMPHOUSE FLOW (MIGD)	TOTALS (1 & 2)
1971	51.2	209.7	260.9
1972	63.5	192.9	256.5
1973	15.2	247.5	262.7
1974	33.1	230.9	264.0
1975	12.6	251.0	263.6
1976	43.4	228.6	272.0
1977	60.0	213.5	273.5

TABLE 3.3b

AVERAGE DAILY BAYWATER FLOW ON A MONTHLY BASIS FOR STELCO 1977

MONTH	TOTAL BAYWATER FLOW (MIGD)
Jan.	257.4
Feb.	263.9
Mar.	278.4
Apr.	276.9
May	276.1
June	273.5
July	286.4
Aug.	283.7
Sept.	278.7
Oct.	286.0
Nov.	277.4
Dec.	241.5
	$\bar{x}$ = 273.5
	s = 13.1

1 MIGD = 5.26 10^{-2} m^3/s

TABLE 3.4

WATER BALANCE FOR STELCO'S HILTON WORKS, 1977

LOCATION OF STREAM			FLOW (MIGD)
INFLUENT			
Baywater Intake	BSPH No 1		60
	BSPH No 2		213.5
City Water Flow to Hilton Works			3.8
	Total		277.2
EFFLUENT*			
City Sanitary Sewer System (Total)			1.2
East Side Lagoon Combined			98.5
composed of			
(i) Hot Strip Finishing (Heavy Gauge Shear Line)		0.29	
(ii) East Side Open Cut Sewer		81.6	
(iii) 60 In Cold Mill to City Storm		13.1	
(iv) Sinter Plant Scrubber and Coke Side Shed precipator		3.5	
North Outfall			16.1
composed of			
(i) Oil Recovery Plant		13.0	
(ii) 148 In Plate Mill		3.1	
No 3 O.H. - BOF Cooling Water			52.1
North Trunk Sewer (N-W Outfall)			60.0
West Side Open Cut Sewer			48.0
	Total		275.9

* Effluent figures are based on average flow measurements made during the period 1975-1977.

1 MIGD = 5.26 10^{-2} m^3/s

TABLE 3.5a

GROSS LOADINGS TO HAMILTON HARBOR FROM DOFASCO

(lb/day Industrial Abatement Div., MOE)

	NOV. 1971	JUNE 1972	SEPT. 1972	JAN. 1973	APRIL 1973	JUNE 1973	AUG. 1975	APRIL 1976
BOD	79,000	63,000	52,000	32,000	44,000	80,000		18,000
COD	270,000	140,000	150,000		210,000	180,000	54,000	99,000
Organic C			11,000	20,000		48,000		
Inorganic C.		33,000	21,000	31,000		32,000		
Total P	440	260	1,000	380		250	180	190
Soluble P			450	240		170		170
Kjel. N	11,000	15,000	16,400	7,300	9,500	20,000		
Ammonia	7,800	17,000	19,000	5,600	7,800	16,000	6,500	6,600
Nitrate		2,400	2,100	3,000	2,600	1,600		
Nitrite		1,200	750	300	370	380		
S.S.	120,000	60,000	100,000	83,000	69,000	132,000	57,000	89,000
TDS	650,000						630,000	730,000
Chlorides	95,000	150,000	160,000	150,000		145,000		
Sulphates		170,000	170,000	180,000		200,000		130,000
Sulphides	100	200	120			380		
Zn	180	1,100	4,200	1,600	1,800	690		680
Fe	13,000	17,000	36,000	7,800	18,000	7,200	7,300	10,800
Cr	60		220	200	380	240		40
F	2,600	3,500	2,900	2,200		1,300		
Mn								780
As								3
Cu								100
Pb								40
Cd								10
Phenols	310	12	4,100	340	1,500	1,300	29	270
Ether Solubles		9,600	19,000	130,000	5,900	18,000		7,500
Cyanides	65	280	190		110	170	320	300

1 lb = 0.454 kg

TABLE 3.5b

GROSS LOADINGS TO HAMILTON HARBOR FROM STELCO (lbs/day)

(Industrial Abatement Division, MOE)

	NOV. 1971	APRIL 1972	MAY 1972	JAN. 1973	APRIL* 1973	JUNE 1974	APRIL 1976
BOD	21,000	23,000	22,000	29,000	15,000	7,000	18,000
COD	103,000	88,000	86,000	105,000	100,000	63,000	130,000
Organic C.		24,000	79,000	34,000			
Inorg. C.		58,000	86,000	83,000			
Total P.	380	620	480	380		580	600
Soluble P.		260	230	250			500
Kjel. N.	68,000	18,000	37,000	29,000	19,000		
Ammonia	26,000	16,000	56,000	17,000	15,000	1,900	7,500
Nitrate		5,400	3,200	4,700	3,600		
Nitrite		1,700	600	600	460		
S.S.	84,000	91,000	104,000	160,000	110,000	64,000	68,000
T.D.S.	950,000					990,000	1,100,000
Chlorides	330,000	183,000	203,000	190,000			
Sulphates		239,000	270,000	850,000			160,000
Sulphides		540	730	1,700			
Zn	1,800	1,000	1,000	1,600	2,200	1,500	3,100
Fe	9,400	19,900	14,000	28,000	11,000	13,000	38,000
Cr		140	230	19,000	80	100	80
F	2,200	2,200	2,500	1,900			
Mn							910
As							6
Cu							120
Pb							80
Cd							25
Phenols	800	13	280	520	530	270	220
Ether Solubles	3,400	11,000	11,000	6,200	7,500		6,900
Cyanides	6,100	1,300	5,500	700	3,300	120	1,500

* No 3 O.H. loadings are missing
1 lb = 0.454 kg

TABLE 3.6a

NET LOADINGS TO HAMILTON HARBOUR FROM DOFASCO (lbs/day)

(Industrial Abatement Division MOE)

	NOV. 1971	JUNE 1972	SEPT. 1972	JAN. 1973	APR. 1973	JUNE 1973	AUG. 1975	APR. 1976
BOD	74,000	49,000	38,000	31,000	39,000	73,000		11,000
COD	220,000	90,000	98,000		200,000	150,000	33,000	39,500
Org. C.			0	2,700		32,000		
Inorg. C.		0	0	0		0		
Total P.	360	140	660	110		0	40	50
Sol. P.			280	0		0		70
Kjel N.	9,600	7,200	13,000	4,700	900	9,000		
Ammonia	6,400	9,400	16,000	1,800	190	5,600	3,800	2,600
Nitrate		540	0	0	200	0		
Nitrite		300	190	80	160	160		
S. S.	100,000	34,000	84,000	66,000	60,000	130,000	32,000	63,000
T.D.S.	150,000						0	0
Chlorides	5,000	33,000	58,000	47,000		22,000		
Sulphates			38,000	60,000		52,000		21,000
Sulphides	0	20	0			250		
Zn	80	220	4,000	1,500	1,600	510		
Fe	12,000	16,000	35,000	6,700	17,000	5,100	6,700	9,500
Cr	20		150	180	360	70		0
F	1,500	1,900	1,500	1,000		1,200		
Mn								630
As								0
Cu								40
Pb								30
Cd								0
Phenols	300	5	4,100	330	1,500	1,300	29	260
Ether Solubles		6,100	17,000	6,000	2,500	13,000	300	3,600
Cyanides	50	260	170		0	170	300	250

1 lb = 0.454 kg

TABLE 3.6b

NET LOADINGS TO HAMILTON HARBOR FROM STELCO (lbs/day)

(Industrial Abatement Division, MOE)

	NOV. 1971	APRIL 1972	APRIL 1973	JUNE 1974	APRIL 1976
BOD	15,000	23,000	15,000	0	14,000
COD	6,000	86,000	97,000	10,000	0
Organic C.		24,000			
Inorg. C.		57,000			
Total P.	220	610		50	0
Soluble P.		250			0
Kjel N.	64,000	18,000	18,000		
Ammonia	26,000	16,000	15,000	900	0
Nitrate		5,300	3,400		
Nitrite		1,700	450		
S.S.	92,000	89,000	110,000	0	40,000
T.D.S.	0			190,000	0
Chlorides	194,000	179,000			
Sulphates		234,000			0
Sulphides		540			
Zn	1,400	1,000	2,100	1,200	1,300
Fe	7,700	19,9000	11,000	13,000	11,000
Cr		130	80	20	0
F	400	2,200			
Mn					290
As					2
Cu					40
Pb					50
Cd					0
Phenols	760	13	530	190	170
Ether Solubles	3,400	11,000	7,400		3,000
Cyanides	6,100	1,300	3,300	90	1,000

1 lb = 0.454 kg

TABLE 3.7

INTAKE AND DISCHARGE LOADINGS TO WEST SIDE OF THE STELCO HIL. .MENT CANADA SURVEY*)

		BSPH No.2	BSPH No. 2	INTAKE MEAN	INTERNATIONAL HARVESTER			W.S.O.C.						No. 3 O.H.			LIGHT OIL PT.		
					Gross Conc.	Net Conc.	Load	Gross Conc.	Net Conc.	Load	Gross Conc.-	. .nc.	Load	Gross Conc.	Net Conc.	Load	Gross Conc.	Net Conc.	Load
		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)
pH	x	8.3	7.9	8.0	7.9	7.9		7.6	7.6		8.0	8.0		7.9	7.9		7.6	7.6	1
	s	0.2	0.2		0.3	0.3		0.3	0.3		0.5	0.5		0.3	0.3		0.3	0.3	
	Range	7.9-8.5	7.5-8.2		7.6-8.3			7.2-8.2	7.2-8.2		7.2-8.9			7.6-8.4			7.3-7.9		
	n	19	20		8				33		36			28			4		
SS	x	13	8	10	19	11	82	27	18	9100	14	6	3390	14	6	2930	7	2	1
	s	10	6		14	11	116	33	32	16400	12	11	6115	15	13	5960	8	4	2
	Range	1-26	2-18		1-34			3-132	0-122		1-56	0-46		1-64	0-54		2-17	0-7	
	n	10	9		6				29		27			18			3		
TDS	x	246	214	223	283	98	575	299	97	48000	265	62	35100	236	45	20200	140	0	0
	s	118	143		192	158	1287	114	80	40300	88	63	35900	98	61	26900	98	0	0
	Range	52-416	24-532		96-556			44-520	0-297		56-416	0-193		40-424	0-201		28-208		
	n	17	19		7				32		29			28			3		
TOC	x	8	8	8	8	2	18	8	2	256	8	1	396	6	0	79	388	380	306
	s	2	3		4	3	34	9	8	893	2	2	871	2	1	423	569	569	504
	Range	6-14	6-16		4-15			5-55	0-47		6-15	0-7		5-13	0-5		94-1400	94-1392	
	n	20	20		8				33		32			29			5		
TKN	x	2.6	2.9	2.8	1.3	0	0	5.7	3.2	1626	19.4	16.6	9280	0.8	0	0	75.1	72.3	51
	s							4.8	4.5	2300	15.6	15.6	8030				28.8	28.8	32
	Range							0.5-25.5	0-22.7		7.1-75.	1.7- 72.2					58-125	55-122	
	n	1	1		1				33		25			1			5		
NH_3	x	1.9	2.0	2.0	0.5	0	0	3.3	1.3	630	8.5	6.5	3740	1.3	0.1	48	14.7	12.7	9
	s	0.6	0.6		0.3			2.0	2.0	980	7.2	7.2	3980	0.8	0.4	167	7.9	7.9	8
	Range	0.9-2.9	1.2-3.3		0.1-1.0			1.6-11.5	0-9.5		2.7-33.	0.6-31		0.6-3.7	0-1.7		8-28	6-26	
	n	20	20		7				33		32			29			5		
Phenol	x	0.01	0.01	0.008	0.01	0	0	.05	0.05	7.1	0.11	0.10	55	0.01	0.00	1.0	46.9	46.9	28.4
	s	0.01	0.01		.01	0		.18	0.18	17.0	0.28	0.28	143	0.01	0.01	3.1	7.9	7.9	4.1
	Range	.005- 0.024	.005- 0.05		.005- 0.14			.005- 1.00	0.0- 0.99		.005- 1.58	0.0- 1.57		.005- 0.41	0.00- 0.04		42- 57.6	40- 57.6	
	n	17	16		5			29			32			26			4		
TCN	x	0.08	0.05	0.06	0.08	6.03	0.1	.42	0.37	110	0.88	0.82	467	0.09	0.04	18.6	37.0	36.9	23.4
	s	0.15	0.05		0.10	0.09	0.2	.96	0.96	236	0.16	1.16	665	0.16	0.15	68.9	3.7	3.7	4.2
	Range	.02- .67	0.01- 0.13		0.02- 0.32			.01- 5.0	0.0- 4.94		.05- 5.5	0.0- 5.44		0.03- 0.87	0.0- 0.81		33-42	33-42	
	n	20	20		8				32		32			29			4		

TABLE 3.7 - continued

		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)
CNS	x	0.4	0.3	0.33	3.6	3.3	34	2.1	1.8	897	3.7	3.4	1960	3.6	3.3	1476	38.2	37.9	25
	s					0.0	0	1.0	1.0	521	2.7	2.7	1550				14.8	14.8	9
	Range							0.6-4.0	0.3-3.7		1.0-12.4	0.7-12.1					29.6-64	29-64	
	n	1	1		1				32		26			1	1				
O&G	x	6	3	4	19	17	44	3	1	292	5	3	1400	3	1	352	65	61	48
	s	14	2		30	29	53	2	1	527	10	10	4840	3	2	796	81	81	78
	Range	1-65	1-7		0-85	0-81		1-7	0-4		1-56	0-52		1-12	0-8		19-210	15-206	
	n	19	20		7				32					29			5		
S	x	1.2	1.4	1.4	0.7	0.1	0.	0.9	0.3	158	0.9	0.3	164	0.4	0.0	10	1.6	0.5	0
	s	1.6	1.8		0.7	0.3	1.	1.4	1.1	553	1.3	1.0	563	0.4	0.1	36	1.9	0.5	
	Range	0.2-6.0	0.2-6.8		0.2-2.3	0-0.9		0.2-7.1	0-5.7		0.2-2.4	0-1.0		0.2-1.7	0.0-0.3		0.2-24	0-1	
	n	20	20		8				31		29			27			5		
Cl	x	63	63	63.1	121	58		83	20		70	8		65	2				
	s	5	6		28	28		11	11		7	7		4	3				
	Range	51-70	54-70		98-170	29-107		68-132	0-69		58-86	0-23		59-72	0-9				
	n	20	20		8				33		32			29					
SO_4		59	57	57.6	70	12		72	15		63	6		59	2				
	s	3	3		12	12		10	9		5	5		3	3				
	Range	55-65	52-61		60-95	0-37		54-91	1-33		53-65	0-18		53-65	0-7				
	n	20	20		8				33		32			29					
F	x	0.9	1.0	0.9	0.6	0.0	3.6	2.1	1.2	567	1.7	0.7	400	0.9	0.0	20			
	s	0.1	0.2		0.3	0.0	9.1	0.5	0.5	235	0.3	0.3	156	0.1	0.1	34			
	Range	0.7-1.1	0.8-1.7		0.3-1.0	0-0.1		0.9-3.2	0-2.3		0.9-2.3	0.5-1.1		0.8-1.2	0.0-0.3				
	n	20	20		7				33		32			29					
Fe_T	x	0.86	0.62	0.69	1.09	0.55	0.0	2.65	2.01	1030	1.00	0.40	169	1.17	0.7	316			
	s	0.83	0.60		1.01	0.90	0.0	4.65	4.63	2360	0.69	0.62	278	1.92	1.83	826			
	Range	0.2-2.8	0.30-2.80		0.2-3.2	0-2.51		0.2-14.0	0.0-19.31		0.3-2.9	0.0-2.21		0.2-6.2	0.00-7.81				
	n	20	19		8				33		32			29					
Cu_T	x	0.09	0.02	0.04	0.01	0.00	0.0	0.13	0.11	56.6	0.04	0.02	5.5	0.12	0.10	44			
	s	0.29	0.03		0.00	0.00	0.0	0.55	0.55	280	0.07	0.06	15.9	0.48	0.47	214			
	Range	.01-1.3	0.01-0.14		0.01-0.01			0.01-3.2	0.0-3.16		0.01-0.28	0.-0.24		0.01-2.6	0.0 2.56				
	n	20	19		8				33		31			29					
Zn_T	x	0.14	0.43	0.35	0.11	0.00	0.0	2.26	1.90	928	0.27	0.05	26.7	0.42	0.22	120			
	s	0.07	0.65		0.04	0.00		1.18	1.18	584	0.17	0.09	53.3	1.05	1.01	572			
	Range	0.1-0.4	0.10-2.6		0.1-0.2			1.0-6.6	0.65-6.25		0.1-0.7	0.-0.35		0.1-5.8	0.0-5.45				
	n	20	20		8				33		31			29					

TABLE 3.7 - continued

		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)
Mn_T	x	0.1	0.1	0.1	0.2	0.0	0.	0.4	0.3	155	0.3	0.1	85	0.1	0.0	4			
	s	0.1	0.1		0.1	0.1		0.1	0.1	66	0.1	0.1	54	0.0	0.0	11			
	Range	0.1- 0.3	0.1- 0.3		0.1- 0.3	0.0- 0.2		0.3- 0.6	0.2- 0.7		0.1- 0.5	0.1- 0.4		0.1 0.2	0.0- 0.1				
	n	20	20		8				33		32			29					
Cr_T	x	0.01	0.01	0.01	0.01	0.00	0.0	0.01	0.00	0.2	0.1	0.00	0.8	0.01	0.00	1.8			
	s	0.005	0.005			0.00		0.00	0.00	0.8		0.01	4.2	0.01	0.01	6.0			
	Range	0.01- 0.02	0.01- 0.02		0.01			0.01- .02	0.0- 0.01		0.01	0.0- 0.04		.01- 0.08	0.00- 0.07				
	n	20	20		8				33		31			29					
Pb_T	x	0.05	0.06	0.06	0.05	0.00	0.00	0.10	0.04	19.2	0.05	0.00	0.8	0.09	0.04	19.5			
	s	0.01	0.05			0.00		0.07	0.07	33.5	0.02	0.02	3.5	0.23	0.23	104			
	Range	0.05- 0.11	0.05- 0.25		0.05			0.05- 0.32	0.00- 0.25		0.05- 0.14	0.00- 0.08		0.05- 1.3	0.00- 1.24				
	n	20	20		8				33		31			29					
Flow	x	77.4	218					50.1			57.2			45.1					
(MIGD)	s	16.5	26.7					0.84			1.87			3.70					
	Range	62.0- 108.0	117- 289					46.4- 52.5			48.2- 57.6			35.0- 53.0					

Notes 1: WSOC = West Side Open Cut; NWO = North West Outfall; No. 3OH = No. 3 Open Hearth Treated Effluent; Light Oil Pt = Light Oil Plant Raw Effluent

2: Composite Sample = BSPH2, BSPH2, WSOC, NWO, No. 3 O.H.,

3: Grab Sample = International Harvester, Light Oil Plant

4: SS = Suspended Solids; TDS = Total Dissolved Solids; TOC = Total Organic Carbon; TKN = Total Kjeldahl Nitrogen; NH_3 = Ammonia; TCN = Total cyanide; CNS = Thiocyanate; O & G = Oil and Grease (Freon Extractable); S = Total Sulfide; Cl = Chloride; SO_4 = Sulfate; F_e = Fluoride; F_T = Total Iron; Cu_T = Total Copper; Zn_T = Total Zinc; Mn_T = Total Manganese; Cr_T = Total Chromium; Pb_T = Total Lead

5: All concentrations are in mg/l except for pH and Flow. All loadings in lb/day. 1 lb = 0.454 kg

* Environment Canada, 1979

TABLE 3.8a

LOADINGS TO HAMILTON HARBOUR CALCULATED BY LAKE SYSTEMS UNIT, WATER RESOURCES BRANCH, MOE

	Ammonia (kgN/day)	Nitrate (kgN/day)	TP (kgP/day)	Fe (kg/day)	TOC (kg/day)	COD (kg/day)	FLOW*** (MIGD)
Stelco							
W.S.O.C.	7,060	470	43	735	3,180	10,100	54
N-W Trunk	1,620	500	43	1,240	3,710	9,900	54.6
No. 3 OH-BOF	780	310	27	1,290	2,110	?	46.6
148"Plate Mill	180	130	8	480	983	?	10.8
E. Side Lagoon	*	*	*	3,850	4,200	*	84.2
Hot Strip Finishing	*	*	*	1,390	56	*	0.355
HCl Regneration	*	*	*	514	308	*	5.67
Heavy Gauge Shear	*	*	*	6	23	*	0.20
No. 1 Intake	-960	-580	-33	-374	-2,880	?	193.
No. 2 Intake	-4,470	-1,820	-148	-472	-7,000	?	63.5
Net Loading	**	**	**	8,660	4,690	?	0
Dofasco							
Ottawa St.	*	*	*	7,710	5,210	*	46.
Lagoon	*	*	*	1,350	3,110	*	76.3
Boiler House				340	1,200		30.0
Coke Oven	420	310	124	340	1,700	18,600	28.8
Silicon Steel Plant				1	35		0.87
Raw Water Intake	-2,900	-890	-112	-635	-7,838	?	173.
Net Loading	**	**	**	9,105	3,440		9.
Ottawa St. Slip	3,810*	1,630*	242*	-	-	45,000	213
Total Stelco/ Dofasco	9,340	66	73	17,800	8,130		--
Hamilton WWTPT+	2,350	24	970	?	?	4,700 as BOD	-
Burlington WWTPT+	60	280	110	?	?		-
Total	11,750	370	1,150	?	?		-

1 MIGD = $5.26\ 10^{-2}\ m^3/s$

* Ottawa St. Slip is the sum of the E. Side Lagoon Hot Strip Finishing, HCl Regeneration and Heavy Gauge Shear discharges of Stelco plus Ottawa St and Lagoon discharges of Dofasco. Value of flow in Ottawa St. Slip was reduced by 212.7/281.4 to reflect erroneous flow value used previously for East Side Lagoon.

** Gross loading for these streams of either Stelco or Dofasco cannot be calculated since the Ottawa St. Slip includes some discharges from each.

*** Flow for East Side Lagoon, No. 1 Intake and No. 2 Intake are changed from those of MOE, 1974 as the originally reported flow rates are in error. Accordingly, the corresponding loadings and net loadings are different from those reported by MOE, 1974. As these loadings are based on four 6-hr composite samples taken between April 1972 and January 1973 by the Industrial Wastes survey, they correspond approximately to the loadings shown in Tables 3.6 and 3.7 for 1972 and 1973.

\+ Based upon monthly composite samples.

TABLE 3.8b
ESTIMATES OF LOADING FROM OTTAWA STREET SLIP (OCT. 1976)

	CONCENTRATION (mg/L) at				LOADING lb/day
Parameter	Surface		2.5 m Depth		
	x	s	x	s	
BOD_5	5.6	1.0	5.4	1.9	13,000
COD	33.3	12.0	29.6	17.8	79,000
TS	344	9.	318	52.	820,000
SS	21	4.	14.5	1.4	50,000
Cond (umhos/cm)	510	8.	454	4	11,000
TURB (FTU)	9.4	3.4	4.6	0.7	5,800
TKN	2.45	0.37	1.10	0.10	5,800
NH_3	1.67	0.30	0.45	0.10	4,000
NO_3	1.91	0.11	1.89	0.16	4,600
NO_2	0.22	0.027	0.196	0.035	530
TP	0.070	0.016	0.041	0.005	180
SP	0.002	0.001	0.002	0.001	5
Cl	70.1	4.6	49.1	1.8	170,000
Fe	8.06	1.69	4.13	0.49	19,000
Mn	0.25	0.03	0.10	0.01	600
Zn	0.14	0.03	0.06	0.01	330
Cu	0.04	0.01	0.02	0.00	100
Pb	0.01	--	0.01	--	--
Cd	0.005	--	0.005	--	--
Cr	0.04	--	0.04	--	--

1 lb = 0.454 kg

4.0 WASTE WATER TREATMENT PLANT DISCHARGES TO HAMILTON HARBOUR

4.1 INTRODUCTION

There are three major waste water treatment plants found in the drainage area of Hamilton Harbour. The Hamilton WWTP discharges to Redhill Creek near the mouth of the creek, the Burlington WWTP discharges directly to the harbour while Dundas discharges to Cootes Paradise. The Hamilton Plant is the largest (2.9 m^3/s, 55 MIGD), Burlington is intermediate (0.63 m^3/s, 12 MIGD), while Dundas is quite small (0.15 m^3/s, 2.8 MIGD). Process data for the Hamilton Plant is shown in tables 4.1 and tables 4.2a and 4.2b; for the Burlington Plant in table 4.3 and for the Dundas Plant in table 4.4a and 4.4b. The process data for Hamilton are averages of monthly data obtained from the Regional Municipality of Hamilton-Wentworth. The process data for Burlington were summarized by the Central Region of the MOE. The process data for Dundas is summarized from MOE, 1977. The concentration of inputs to the harbour from the Hamilton and Burlington WWTP's are included in Appendix A-3.

4.2 POLLUTANT REDUCTIONS AT HAMILTON WWTP

The Hamilton WWTP attained the following removal efficiencies in 1977: BOD-85%, COD-80%, SS-90%, $\sum(NH_3 + NO_2^- + NO_3^-)$ approximately 5%, TP-80%, and Fe-90%. In 1976 the efficiencies were BOD-89%, COD-86%, $\sum(NH_3 + NO_2^- + NO_3^-)$ approximately 17%, TP-89%, and Fe-86%. Overall, there is adequate removal of organic carbon parameters (BOD, COD, SS), but the plant does not consistently attain design values (90%). The removal of organics on a BOD_5 and COD basis is essentially the same but the BOD_5 values are only a fraction of COD values indicating that the BOD_5 test is inhibited and/or that many of the organics are not really oxidizable biologically. In 1976, there was essentially no nitrification (oxidation of ammonia to nitrate), but 1977 shows a small degree of nitrification. Actually the plant attains approximately 25% nitrification from July onward into 1978 but as there is no nitrate data for October, November and December, the average nitrate concentrations (and hence the degree of nitrification achieved and reported in table 4.1) is too low.

Hamilton has perhaps one of the more unusual treatment plants in Ontario since the effluent concentrations for total phosphorus, which are reasonably close to IJC objectives of 1 mg/L were attained in both 1976 and 1977 without use of a chemical precipitant. Normally, addition of aluminum or iron salts is required. Biological removal has been demonstrated to achieve removals in the range of 20% to 40%. As Hamilton employs only biological removal, it is not conceivable that 80% removal of phophorus can be attributed to the biological treatment processes in the plant. It is this writer's premise that the removals are achieved by the large quantities of iron present in the influent. This iron is probably not in a fresh amorphous form such as would be formed if an iron salt were added to the WWTP to cause chemical precipitation of phosphorus, but it is probably capable of absorbing and/or precipitating sufficient phosphorus. If iron inputs to the plant were to decrease in the future it is quite probable that actual removals of phosphorus would decrease, necessitating chemical precipitation as a plant process.

4.3 POLLUTANT REDUCTIONS AT BURLINGTON WWTP

Process data for Burlington are shown in Table 4.3 for the period 1971 to 1977. The efficiency of removal for 1977 are: BOD-91%, TP-89%, SS-95%, and total nitrogen-70%. Since 1971 the area served by the Skyway plant has increased to approximately 90% of Burlington with a commensurate doubling of hydraulic flow. Even though plant expansion did not occur until 1975-1976, removal efficiencies for BOD and COD are approximately the same for the entire period. The removal efficiency for phosphorus increased from 40% to 90% due to the decreased phosphorus content in the influent and to the chemical precipitation in the plant. Nitrogen removal of approximately 70% has been attained by biological removal (secondary activated sludge); this high removal is made possible by operating a plant as an extended aeration plant with a long sludge-age. Of the total nitrogen entering the plant, approximately one-half is as organic nitrogen, most probably as a particulate phase. Assuming that all of the organic nitrogen settles out in the plant, then only an

average of 40% of soluble nitrogen ($NH_3 + NO_3^-$) was removed during this period. An upset in the plant operations is noticeable in 1976 since the organic nitrogen concentration is high and the nitrate concentrations are low. This upset was probably caused by plant expansion and an attendant lack of nitrification.

This operating data for nitrogen is typical of many extended aeration plants in Ontario. A review of full scale operation of nitrifying plants in Ontario was made in 1973. As effluent standards for extended aeration plants,

44% had 0 mg/L $\leq NH_3 \leq$ 3 mg/L and 7 mg/L $\leq NO_3^- \leq$ 10 mg/L,
34% had 4 mg/L $\leq NH_3 \leq$ 10 mg/L and 1 mg/L $\leq NO_3^- \leq$ 6 mg/L
22% had 11 mg/L $\leq NH_3 \leq$ 20 mg/L and 0 mg/L $\leq NO_3^- \leq$ 1 mg/L.

Of the regular activated sludge plants

31% had 0 mg/L $\leq NH_3 \leq$ 3 mg/L and 8 mg/L $\leq NO_3^- \leq$ 12 mg/L,
30% had 4 mg/L $\leq NH_3 \leq$ 10 mg/L and 4 mg/L $\leq NO_3^- \leq$ 8 mg/L
29% had 11 mg/L $\leq NH_3 \leq$ 20 mg/L and 0 mg/L $\leq NO_3^- \leq$ 3 mg/L.

That is, the majority of extended aeration plants had higher nitrate than ammonia concentrations although a large portion failed to produce any significant nitrification.

4.4 LOADINGS INTO COOTES PARADISE

From June to September 1975, the West-Central Region of MOE measured the inputs from various streams to Cootes Paradise. The inputs from the Dundas WWTP were measured the period of December 1974 to May 1975 (MOE 1977). These results are shown in Table 4.4a. The Dundas WWTP is the largest source of inputs of phosphorus and ammonia but only a minor source of suspended solids and chlorides. The data for several years indicate that 1975 was the high of a 4-year period due both to the higher flow rate in 1975 (Table 4.4b) and to improved treatment in later years.

TABLE 4.1

SUMMARY OF OPERATING DATA FOR
HAMILTON WASTEWATER TREATMENT PLANT

	FLOW MIGD*	SUSPENDED SOLIDS (mg/L)			BOD (mg/L)			TP (mg/L)		
		INTAKE	DISCHARGE	% REMOVAL	INTAKE	DISCHARGE	% REMOVAL	INTAKE	DISCHARGE	% REMOVAL
[illegible]	37.1	216	73	66						
[illegible]	36.3	327	77	77						
[illegible]	36.1	315	73 •	77						
[illegible]	43.8	439	63	86						
1969	47.4	249	66	69						
1970	49.1	261	71	70						
1971	49.0	265	81	67						
1975	52.7	1110	74	93	260	32	88	14.0	1.9	86
1976	55.4				185	20	89	13.2	1.5	89
1977	55.9	289	32	89	143	21	86	6.1	1.3	79

* MIGD = 5.26 10^{-2} m^3/s

TABLE 4.2a
ANNUAL AVERAGES OF PROCESS DATA FOR HAMILTON WWTP
1976

	INFLUENT		PLANT EFFLUENT	
	$\overline{X}$*	s	$\overline{X}$	s
FLOW	55.4	4.4		
BOD	185	41	20.1	6.4
COD	787	231	109	31
NH_3	47.6	13.6	39.4	10.6
TP	13.2	4.4	1.5	0.36
SP	2.9	1.4	0.39	0.17
Fe	18.7	4.1	2.7	1.7
Cl	157	44		
NO_3			0.22	0.24
NO_2			0.32	0.32

*$\overline{X}$ = mean, s = standard deviation of monthly averages
Units are mg/L, except for flow = MIGD

1 MIGD = 5.26 10^{-2} m^3/s

TABLE 4.2b
ANNUAL AVERAGES OF PROCESS DATA FOR HAMILTON WWTP
1977

	INFLUENT		PRIMARY EFFLUENT		SECONDARY EFFLUENT		PLANT EFFLUENT	
	$\overline{X}$	s	$\overline{X}$	s	$\overline{X}$	s	$\overline{X}$	s
FLOW	56.2	6.0						
BOD	146	29	97	37	27	16	21	6
COD	396	76	296	140	83	17	79	14
TS	829	125	677	80		573	52	
SS	293	77	114	27	36	13	29	10
NH_3	48.3	7.0	40.9	12.1	35	20	41.8	8.3
NO_2				0.27	0.15			
NO_3				3.4	4.0			
TP	6.0	1.9	3.2	0.7	1.5	0.6	1.29	0.45
SP	2.0	0.42	1.6	0.4	1.1	0.4	0.77	0.33
Fe	11.0	3.6	5.0	1.9	1.3	0.5	1.18	0.55
Cl	157	51.						
pH				7.6	0.2			
ALK				149	31			

Units are mg/L, except for Flow = MIGD

1 MIGD = 5.26 10^{-2} m^3/s

TABLE 4.3
OPERATING DATA FOR BURLINGTON
SKYWAY WWTP FOR 1971 -1977

	1971	1972	1973	1974	1975	1976	1977
FLOW	5.6	8.1	9.4	9.7	9.4	12	13
BOD IN	199	170	135	124	123	144	183
OUT	8	9	10	8	7	13	16
TP IN	9.2	7.1	6.7	6.5	7.5	8.3	7.4
OUT	4	3.2	2.2	2.9	1.9	1.0	0.8
NO_3 IN	0.104	0.17	0.11	0.23	0.27	0.2	0.1
NO_3 OUT	8.6	5.8	6.9	9.1	7.4	1.6	2.5
NH_3 IN	20	15	13	17		16	20
NH_3 OUT	2.6	1.2	2	1.3		9.2	8
TKN IN	37	39	29	32	35	36	39
TKN OUT	4.1	4	3	3	4	29	9
SS IN	242	240	241	221	260	235	318
OUT	10	13	14	20	17	25	16

Units are mg/L, except for Flow = MIGD

1 MIGD = 5.26 10^{-2} m^3/s

TABLE 4.4a

LOADINGS* FROM DUNDAS WWTP TO COOTES PARADISE 1975

	CONCENTRATION IN EFFLUENT	DUNDAS LOADING TO COOTES	TOTAL LOADING TO COOTES DURING STUDY PERIOD	ESTIMATED PERCENT OF TOTAL LOADING TO COOTES PARADISE DUE TO WWTP BY SEASON			
	mg/L	kg/day	kg/day	Winter	Spring	Summer	Fall
TOTAL P	3.9	45	51	51	54	85	74
SOLUBLE P	2.7	31	33	85	72	93	93
NH_3 N	15.2	176	177	88	87	97	97
ORGANIC N	45	52	83	28	18	55	30
NITRATE N	2.5	28	89				
TOTAL N	22.5	260	349				
BOD_5	32	370	464	44	38	78	57
SS	43	501	2650	9	9	25	13
CHLORIDE	93	1070	3660	14	10	37	27
TOTAL IRON	.35	4	76				
COPPER	.008	0.1	1.3				
ARSENIC	.0004	0.004	0.13				

* based on flow of 2.5 MIGD = 0.13 m^3/s

TABLE 4.4b
DISCHARGES FROM DUNDAS WWTP, 1974-1977

PARAMETER	LOADING (kg/day) 1974	1975	1976	1977	CONC (mg/L) 1977
BOD	170	440	170	150	20.5
SS	120	510	280	210	28
TP	36	50	12	8	1.1
FLOW (MIGD)	1.74	2.5	1.8	1.64	

1 MIGD = 5.26 10^{-2} m^3/s

5.0 STORMWATER AND SURFACE STREAM DISCHARGES TO HAMILTON HARBOUR

5.1 STORMWATER DISCHARGES

Stormwater is discharged to Hamilton Harbour both from stormwater sewers and from combined sewer systems. Discharges from the City of Burlington drain at distinct points which are predominantly creeks: Burlington Open Channel, Falcon Creek, Aldershot Creek and Grindstone Creek. Accordingly these discharges are considered in this report under surface streams. Discharges from the City of Hamilton may be divided into two distinct areas: the mountain and below the mountain. On the mountain either Redhill Creek (discharge to Harbour) or Chedoke Creek (discharge to Cootes Paradise) drain the surface areas. As the storm sewers and combined sewers on the mountain discharge into surface streams, such mountain areas are not considered in this section. Areas below the mountain discharge stormwater directly to the harbour except for a few discharges which flow into Redhill Creek at the most easterly end of Hamilton.

5.1.1 Sewerage System in Hamilton

Like many older urban regions, the area of Hamilton below the mountain is served by a predominantly combined sewer system. During dry weather, sanitary sewage is diverted into the cross-town interceptor. It starts at the pumping station at Marshall and Barton Street intersection, follows MacNab, Ferrie, and Burlington Streets and thence to the Woodward Avenue Wastewater Treatment Plant. The interceptor is about 3 m below ground in the James Street area and deepens to 21 m at the treatment plant. When the combined sewer flows exceed plant capacity (rated at 4.7 m^3/s, 90 MIGD) during wet weather, the storm sewerage is partially or totally diverted to Hamilton Harbour, Chedoke Creek, Red Hill Creek or Cootes Paradise at outfall points. Most diversions are effected by remotely controlled gates, but a few, such as James Street, are diverted by manual adjustment of overflow gates. Accordingly the exact amount of sewage diverted and the length of diversions is unknown as they are not routinely measured except in a few specific studies. In addition and despite the diversions in the sewer system, the wastewater treatment plant itself becomes occasionally overloaded when units are out of service, necessitating partial by-pass at the plant.

Various methods for the control of the quality and quantity of by-passing are available. These include more frequent street sweepings, insitu treatment (e.g. devices that concentrate solids by inertial forces such as rotary screens, and/or other screening devices), wastewater treatment plant expansion for total treatment, real time control of the by-passes to minimize the amount of diversion, and sewer separation. The latter method is practiced as older sewers are replaced. Separation as a crash program may not be feasible from a cost point of view.

5.1.2 Storm Water Loadings

In fact, as more evidence accumulates it becomes clear that storm sewage itself contributes substantial loadings of contaminants to some water bodies. For some water bodies it is argued that stormwater causes a higher loading than treated waste waters. This question for Hamilton Harbor is addressed in Section 7.0. Evaluation of these control alternatives is currently being carried out by various agencies and consultants.

Stormwater discharges and overflows to Hamilton Harbour were first evaluated by the OWRC in 1967 (OWRC 1968). Seventeen major discharge points were examined and are shown in figure 2.1 Colour photographs of the discharges were included in that report. A summary of comments describing each discharge is shown in table 5.1a. A few measurements of water quality allowed the estimation of loadings for three outfalls (see Table 5.1b). The estimates were made by multiplying the concentration times the flow on the day of sampling. If the average annual runoff rate is significantly different from that measured on those few sampling days, significant errors can be expected in these estimated loadings.

5.1.3 Study by J. F. MacLaren Limited

MacLaren (1978) studied the hydraulic characteristics and estimated pollutant loadings (BOD, suspended solids) discharged from a 4.9 km^2 area bounded by Hamilton Harbour south to Concession Street and lying between Emerald Street and Queen Street. The area contains the downtown core of Hamilton. The primarly commercial and residential land area is serviced by a complex network of combined and partially separated storm sewers. The area considered consists

of four sub-basins drained by outfalls on James Street, Catherine Street, Ferguson Avenue and Wellington Street. In dry weather, the sanitary and combined sewers carry flow to the trunk interceptor described above. In wet weather, the combined sewage in excess of interceptor capacity overflows either directly to Hamilton Harbour or at several upstream points to storm relief sewers which subsequently drain to the harbour. Hence consideration of the four sub-basins separately presents problems. For pollutant discharge purposes MacLaren's considered two areas whose characteristics are shown in table 5.2. Since the Wellington Street basin is interconnected to the James Street basin at Cannon and to the Catherine Street basin at Robert Street, even this subdivision is approximate.

The sewer system was initially analysed in detail using the SWMM model (Storm Water Management Model; Environment Canada, 1976; U.S. EPA, 1971) in order to evaluate current conditions of excessive discharge. The criterion for excessive discharge was that computed water levels must be 1.8 m below street level. This evaluation gave an overall coefficient of imperviousness of 0.51. The estimate of pollutant loads and their possible diminution was studied using the STORM model. Because STORM is quite simplistic in its presentation of the system, measurements are required to calibrate flow predictions. Overflow data from Ferguson Street at Ferrie Street was used for quantity calibration. As flow data were not available, the dates, frequencies and durations of overflow events were used for calibration. Figure 5.1 shows that the observed data were not reproduced exactly. The simulated duration (127 hours) agreed quite closely with recorded duration (122 hours) of overflow. MacLaren asserts that a closer agreement should not be expected due to the complex interconnections. The calibrated interception rate is approximately 1.5 times the dry weather flow.

To calibrate quality predictions, measurements are necessary. In this case, a data base consisting of BOD, suspended solids, total phosphorus, chloride and conductivity from James Street at Guise Street for the period of July to November 1977 was used. The data are shown in Appendix A.3.

Overall, six events were sampled. The July 6 (two events), July 7, and August 8 events result from distinct short summmer thunderstorms. The November 7 and November 10 samplings represent more gentle rains. For the summer storms, all parameters (BOD, suspended solids, total phosphorus, conductivity, chloride) show a relationship with flow. The first three increase with increasing flow while chloride and conductivity decrease. Such parameters are called flow sensitive. Total phosphorus, BOD and suspended solids increase with flow because they are associated with particulates which are eroded from sewer deposits deposited during the previous dry weather. Parameters like chloride and conductivity decrease due to dilution of some constant continuous source.

To estimate loadings for BOD and suspended solids, MacLaren used the average concentration of these parameters from all events. Their rationale was that the length of rainfalls and runoff times were all short (less than an hour) and since the minimum time step for the STORM model is an hour, average concentrations were appropriate. In fact, the use of average concentrations is appropriate only as long as one is considering parameters. In Appendix A-2 a small study is presented on calculating loading estimates for total phosphorus for differing degrees of relationship between total phosphorus and flow. It essentially shows that substantial errors are introduced where a sufficiently strong flow concentration relationship exists. Proper modelling needs to consider such relationships. However, given the coarseness of the model STORM for estimating pollutant discharges, such relationships may be only a second order refinement.

For pollutant loadings the measured and calibrated average values are 32 mg/L for BOD and 230 mg/L for suspended solids. These values are similar to average provincial data (40 mg/L for BOD, 220 mg/L for suspended solids). Model estimates of flow and of BOD and suspended solids loadings are shown in table 5.2. The predicted number of overflows for the two areas is the same, but the annual

overflow volume and pollutant discharge for Wellington Street is 20% higher than for the Ferguson Street complex. MacLaren attributed this higher pollutant discharge to the larger portion of commercial and industrial land use in the Wellington Street basin. This is impossible as they have calibrated the quality portion of the model to the same concentrations of BOD and suspended solids for each area. The difference instead lies in a different degree of imperviousness and the higher amount of runoff.

The estimates of loading show a good comparison with the estimate of table 6.1. As similar chemical data is used the small differences are due to the overflow runoff values used-18 cm (7 in) by MacLaren, 24 cm (9.4 in) used in this report.

Since various studies have shown an approximate linear decrease in the export of BOD and suspended solids as the interval between street sweepings is decreased from 20 days to 1 day, MacLaren examined in situ storage requirements (additional construction beyond sewer system storage) and the effects of street sweeping as alternative control methods. They concluded that street sweeping and dynamic regulation are the most cost-effective solutions coupled with the proposed expansion of the municipal wastewater treatment plant (4.7 to 7.4 m^3/s (90 to 140 MIGD) rated capacity).

5.1.4 Study by Gore and Storrie Limited

Gore and Storrie (1977) evaluated the quality and quantity predictions of the SWMM model by gathering data on quantity and quality from a 71 ha (176 acre) catchment on Hamilton Mountain. The catchment, a portion of the area bounded by Upper Ottawa, Upper Kenilworth, Fennell and Mohawk Streets, is serviced by a combined sewer system and is located close to the area (see below) studied by Proctor and Redfern (1977). The area has essentially a suburban character (detached housing: 70-80%, semi-detached:2%, apartments:6%, schools:2% and open space:10-20%) but was significantly developed during the study period.

For quantity simulation, 78 sub-catchments were modelled using the RUNOFF block of SWMM and routed through the sewer system using the TRANSPORT block. Individual runoff coefficients were estimated for each sub-catchment; the overall average imperviousness was 36%. For modelling, data from two rain gauges were used as input to the basin and runoff rates were measured for model calibration and verification. Depression storage (ponding on pavement), ground water infiltration potential, and evaporation were estimated. Depression storage - a calibration parameter - is particularly important for minor rainfall and runoff events. Infiltration was described using the integrated form of the Horton infiltration model.

Initial simulations showed a major problem. Comparison of model predictions with observations indicated that a substantial volume of water lost to the ground via infiltration re-entered the system. This re-entry was attributed to foundation drains. The effect became especially important for large rainfalls which provided water volumes sufficient for saturating the soil above the foundation drains. The model was conceptually modified to make the runoff coefficient a function of rainfall volume; mathematically, the model was modified by making the infiltration parameters in the Horton equations smaller as the rainfall progressed. This is the simplest modification as construction of two hydrographs- one surface and one subsurface-is quite difficult mechanistically. Charts of measured and predicted hydrographs were shown in the appendix of the report not available to this writer. A summary is shown in Table 5.3. The agreement is described as fair to good with the occasional one showing an excellent match. As Gore and Storrie note, these excellent matches must be attributed more to chance than to modelling and simulation performance. At this time, the model appears to be excellently calibrated but not verified for quantity predictions as all hydrographs were probably used for assessing the modification to the Horton equation.

For quality predictions, 20 rain events with an average of 17 samples per event were sampled and analyzed for 15 parameters. The parameters used were suspended solids, total suspended solids, total solids, volatile solids, BOD, COD, ammonia, nitrate, total phosphorus, barium, cadmium, chromium, copper, lead, nickel and zinc. Also three non-event periods were sampled to obtain a generalized picture of dry weather flows. The event data show a "first flush" phenomenon for all chemographs; that is, the chemograph peak is almost always associated with the initial increase in flow and shows a rapid decrease after the initial peak. This "first flush" phenomenon is caused by a relatively flat sewer network and continuous construction activity which causes sedimentation during the dry weather periods. As the James Street site shows a lack of "first flush" characteristics, it probably has a steeper character. Calculations of mass loading from stormwater were not made by Gore and Storrie because of missing data from the start of the runoff period. The data gaps were caused by a delay in activation of the sampler. For dry weather periods, their normalized weekly loading pattern of total suspended solids, BOD and flow is shown in Figure 5.2. This data provides base level information if overflow occurs. Their average per capita loadings in g/person of BOD-22, suspended solids-47, COD-64 and total phosphorus-1.7 are lower than average North American values for BOD and suspended solids but approximately equal for COD and total phosphorus.

For quality predictions, two 1976 storms were selected. The accumulation of dirt and its pollutant content (Table 5.4a and 5.4b), the number of dry days between storms, frequency of street sweeping and catch basin volumes are major factors controlling model predictions. The results of the simulations show the predicted BOD and suspended solids are notably lower than measured concentrations.

Gore and Storrie conclude that flow simulations can be made without calibration, and without considering the infiltration modifications, provided rainfall measurements are accurate and runoff coefficients are chosen with adequate care and common sense. Although hydrograph predictions show reasonable agreement with observations, chemograph

predictions were unsatisfactory. The time behaviour of the chemograph is distorted due to underestimation of pollutants washed off and due to an inadequate simulation of suspension and transport of pollutants. Mass export predictions for BOD and suspended solids probably provide an order of magnitude value for a potential overflow point.

5.1.5 Study by Proctor and Redfern Limited

Proctor and Redfern (1977) estimated the frequency and quality of stormwater overflows using STORM (US Army Corps of Engineers, 1976), a computer model for estimating volume of runoff given hydrological and physical data. The estimates were made for the Greenhill Avenue trunk sewer which serves 1170 ha (2900 acres) of combined sewer system plus 1090 ha (2700 acres) of sanitary system. Overflows from the combined system drain into Redhill Creek. The area drained is 80% single family residential and is relatively flat, lying at the edge of Niagara Escarpment in east Hamilton. Annual precipitation is approximately 76 cm (30 in) of which 10% to 15% falls as snow. The precipitation occurs as 40-60 individual events. During dry weather, all sanitary flows are diverted into the sanitary interceptor which flows to the Woodward Avenue treatment plant. When the treatment plant's capacity is exceeded, closure of the regulator at Greenhill causes complete overflow until reopened.

Estimates of overflow by STORM were calibrated by comparison with actual measurements for 26 events during 1975 to 1977, using rainfall data from the Royal Botanical Gardens rain gauge. The calibrated runoff coeffients are shown in Table 5.5. A typical storm pattern is shown in Figure 5.3 for June 30, 1974. Estimates of sanitary components including wet weather infiltration were made for the various recorded events. Sanitary flows are estimated to average 30% of the total volume during overflows. Measurements for calibration are not available for estimates of pollutant exports from the basin. Hence estimates of Proctor and Redfern are based upon the assumptions in Table 5.4b gleaned from the literature.

Using rainfall data for 14 years, the following annual estimates were made.

No of Overflows/year	-	49
Volume of Overflows	-	3.3×10^6 m^3/yr (730 MG/yr)
BOD Loading	-	960 kg/day (2100 lb/day)
Suspended Solids Loading	-	2700 kg/day (6000 lb/day)

Comparison with other cities (Figure 5.4) indicate that these BOD estimates are higher than for several other cities. The authors argue that these predictions are reasonable since the heavy industry in Hamilton should cause high surface accumulation rates of dust and dirt. This contention is probably not reasonable as the Greenhill drainage area is located some distance up-wind of the heavy industrial areas. If estimates are too high, it is no doubt due to erroneous assumptions concerning dust accumulation rates and the characteristics of the dust.

Runoff measurements have been made periodically on Redhill Creek at Barton Street by MOE. The minimum flow is of the order of 0.01 m^3/s (0.4 cfs) and the average July flow is 0.071 m^3/s (2.5 cfs). Estimates for July for 1975-1977 (Section 1) range from 3.9 to 5.5 m^3/s (140 to 200 cfs). Accordingly, compared to the average observed peak overflow rate from the Greenhill sewer - 10 m^3/s (360 cfs) and an average observed peak overflow rate for all 1974-1975 storms of 0.2 m^3/s (8 cfs), little dilution of the overflow can be expected in Redhill Creek during summer periods. Hence, sampling programs designed to estimate export of materials from Redhill Creek to the Harbour will miss substantial information unless samples are collected during and shortly after cessation of rainfall events.

5.1.6 Study by C.C.I.W.

Marsalek (1977, 1978a, 1978b) has developed a simpler methodology for estimating pollutant discharges. It is essentially a regression model approach, producing a table of unit loads per person or per acre as a function of basin characteristics. His original work was based upon a study of the Malvern (Burlington) catchment 23 ha (58 acres, 1000 people, 100% single family residential, 31% impervious) which has completely separated storm and sanitary sewers. The catchment eventually drains in to Lake Ontario rather than Hamilton Harbour.

The study monitored the quality and quantity of runoff during the spring and summer of 1976 from 19 events whose rainfall varied from less than 2.5 to 30 mm. Stepwise regression analyses were made between export and the basin/pollutant variables. The most significant initial model had the form W = a + bt + ci where a is the initial pollutant accumulation at zero time, t is the antecedent dry weather period, b is the daily rate of accumulation of the pollutant in the catchment, i is the peak rainfall intensity over 5 minutes and c is the efficiency of pollutant removal from the catchment. In fact, a becomes negligible for long dry periods and c does not explain much of the regression. Since the Malvern data is only for the spring and summer, results from the study of Droste and Hartt (1974) for a similar residential area in Windsor were used to generate a seasonal variation. As street sweeping removes approximately 70% of solids accumulated on the street, it should be included in the model. However since Malvern sweeps its streets only once a year, the effect of sweeping is in this case insignificant. The final model form for the monthly loads then becomes

$$L = b \sum_{j=1}^{n} t_j - E \sum_{k=1}^{m} t_k$$

where $\sum t_j$ represents the sum of antecedent dry days of all events during a month, $\sum t_k$ represents the sum of the number of street sweeping days per month and E is the efficiency of street sweeping.

Predicted annual loads and mean concentrations are, respectively:

		kg/ha	mg/L
Total solids	-	760	110
Volatile solids	-	170	24
COD	-	120	17
Nitrogen	-	30	4.1
BOD	-	82	11
Phosphorus	-	3.3	0.46
Lead	-	0.32	0.044

For residential areas of approximately similar density and character, these would represent the minimum concentrations and loadings expected in stormwater runoff from separated stormwater sewerage. Combined sewerage would be expected to increase these concentrations and loadings.

This work poses a fundamental question: are regression estimates or a mechanistic model the most powerful tools for estimating pollutant discharges in stormwater discharges or combined sewer overflows? As processes controlling the quality of urban runoff are poorly understood, further advances are unpredictable. Mechanistic models such as SWMM have proven quite adequate for hydrograph predictions if the rainfall characteristics are known and if one has a good common sense knowledge of calibration parameters (e.g. antecedant moisture; infiltration parameters, percent imperviousness). Unfortunately, predictions of concentrations and loadings of chemicals are as yet quite unreliable, particularly for combined sewerage overflows. The major gap of knowledge appears to be the accumulation of pollutants between rainfall events. Compare the modelling of a hydrograph to that of a chemograph. Knowledge of hydraulic inputs to the catchment (rainfall) are known much more precisely than inputs of pollutants. If pollutant inputs (for example, dry weather accumulation), were known as precisely as rainfall inputs, then prediction of loadings should involve only common sense model calibration, assuming that removal processes are sufficiently well understood. At present mechanistic models for loading predictions remain at low level of development and require extensive calibration.

In fact, Marsalek (1979) asserts that if one assumes that the catchment is completely cleaned by runoff and street sweeping annually, then catchment hydrology becomes of secondary importance in estimating annual loadings. That is, the annual loadings for a storm sewer system are equal to surface accumulation minus the amount removed by street sweeping. Marsalek tested this hypothesis by comparing the 10 year prediction made by the SWMM model, calibrated for water quality on a small American catchment, to the

prediction of an annual unit load approach. For BOD, phosphorus, cadmium, lead and zinc, the differences between the two approaches is about 19%. For suspended solids the difference is 100%. As SWMM was not that well calibrated for suspended solids, the difference is not surprising. The small difference for the other parameters is statistically insignificant.

Such arguments then suggest that the best approach is use of a unit load approach together with the export coefficients shown in Table 5.6. Potential shortcomings of using annual or monthly loads can occur where one event (e.g. carrying 10% of the annual load) causes a shock loading to a water body. Then use of a mechanistic model is necessary, although, given the large data requirements for calibration and current difficulties with model verification, accurate estimation of pollutant concentration for such short-term events is not probable.

5.1.7 General Estimates of Loadings From Storm Sewers

An extension of the unit load approach (export of pollutant per unit area for different land uses) is the use of general estimates made by various agencies. These estimates are imprecise for specific applications, being based upon extrapolation from other urban areas. Accordingly, their specific application to Hamilton Harbour is limited. Their strength is that, because they are based on several different areas, they provide a relative estimate of export when one is comparing different areas. They are included here for sake of completeness.

Two sets of estimates of unit loadings are of note. One is made by the American Public Works Association (APWA 1969), based upon North American data, another is made by the Ontario Ministry of the Environment for urban effects of diffuse source input to the Great Lakes (PLUARG).

A summary of the unit load estimates for the various studies is shown in Table 5.6. There is considerable variation in the estimates. The PLUARG estimates, being based upon Ontario data, may be somewhat more useful than the APWA estimates.

The APWA data allows the estimation of loads to the wastewater treatment plant, combined sewer overflows and surface streams. The basic parameters used for APWA estimates (see Table 5.7) appear to have a few problems. The annual dry weather flow in Hamilton in combined sewers is estimated to have a much higher flow per unit time than that of wet weather flow, since wet weather flows, which occur for 20-30 days each year and dry weather flows which occur for 330-340 days are both averaged over the full year. If it is assumed that Hamilton's dry weather flow (46.5 cm/yr, 18.3 in/yr) is fully treated by the wastewater treatment plant, then this flow accounts for only a portion of the total annual flow to the wastewater treatment plant (95.8 cm, 37.7 in/yr). Even if the annual wet weather estimates are added to the dry weather estimates, the total flow estimate (81.3 cm, 32 in/yr) is too low. The difference between predicted dry weather flow and actual WWTP flow is industrial water usages and discharges to the municipal sewer system. The daily per capita water consumption in Hamilton of 250 gal (1.14 m^3), based on 750 MIGD and 300,000 people, is approximately double the municipal average for North America of 125 gal (0.57 m^3).

The weakness of the unit load approach is that it assumes constant conditions from year to year. In fact, there is a variation of up to 50% in annual precipitation and an expected similar variation in flow. As the erosion and hence export of BOD and suspended solids is dependent upon the flow rate, a similar variation in these chemical parameters is expected. The James Street outfall was monitored for several rainstorms in 1977 by this author. The data (see Appendix A.1) show that BOD and suspended solids concentrations increase as flow increases - an erosional affect - while chloride concentrations decrease with increasing flow - a dilutional effect - over the course of a hydrograph. Such relationships have substantial effects upon estimates of export, depending upon the strength of the relationship between concentration and flow. Hence for harbour phenomena which have short time scales (for example, one week or less) and which are impacted heavily by such events, the

knowledge of these short term variations is essential. Further, for those chemical parameters dominated by inputs from surface water runoff, annual variations in hydrological inputs affect the year by year variation of harbour water quality.

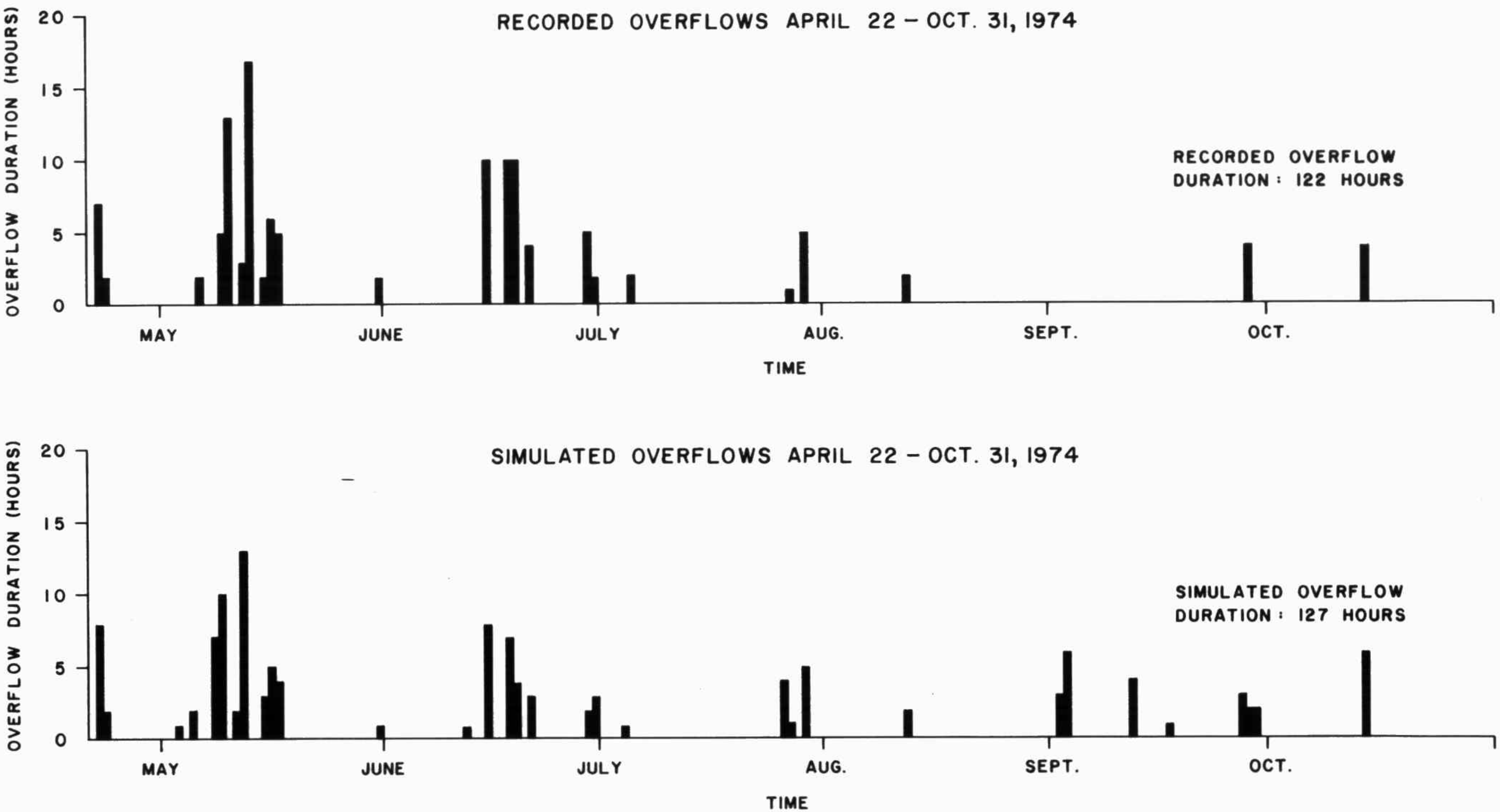


FIGURE 5.1 – QUANTITY CALIBRATION OF THE MODEL, STORM (MacLARENS, 1978)

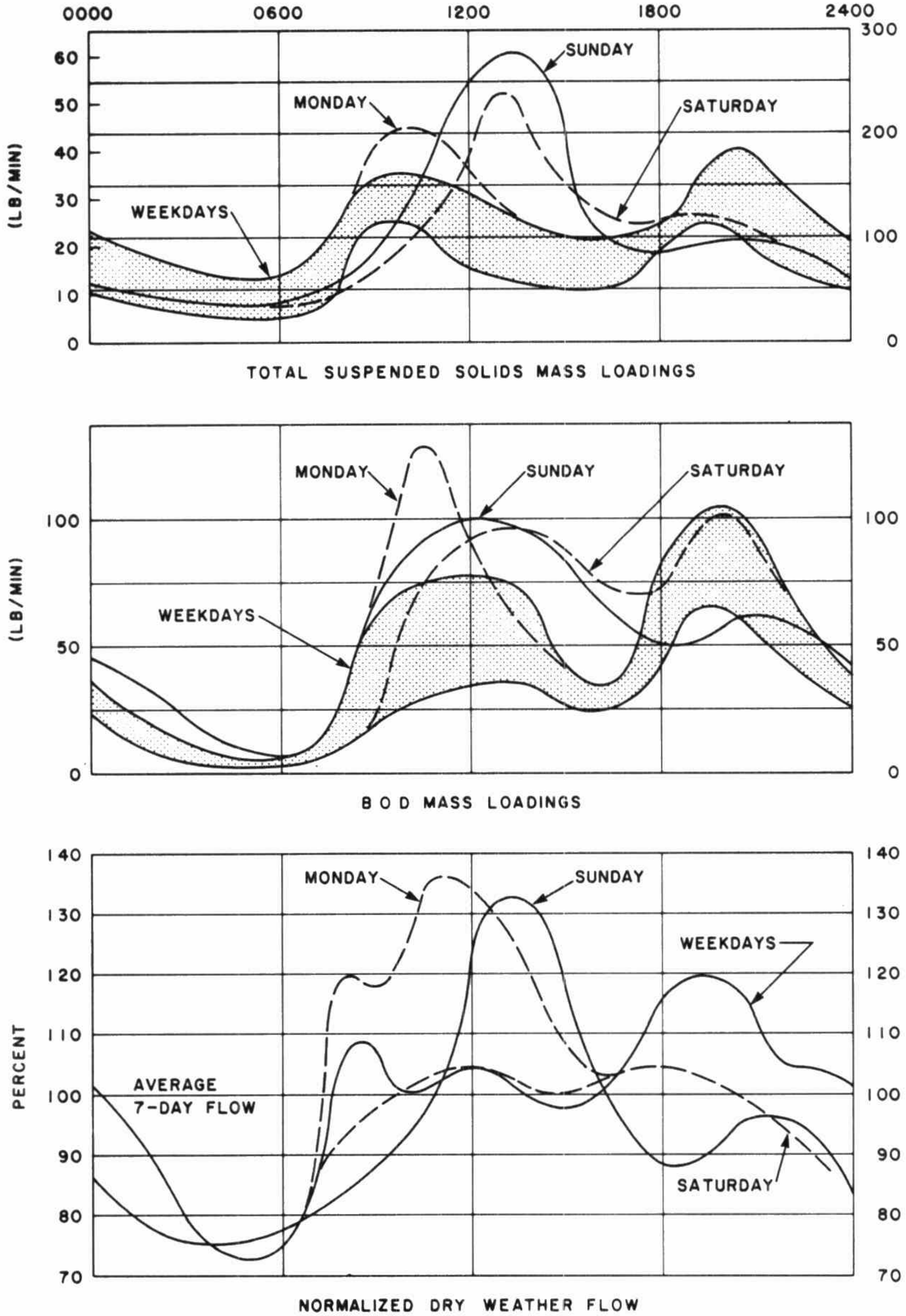


FIGURE 5.2 - NORMALIZED MASS AND FLOW PATTERNS OBSERVED BY GORE & STORRIE, 1977

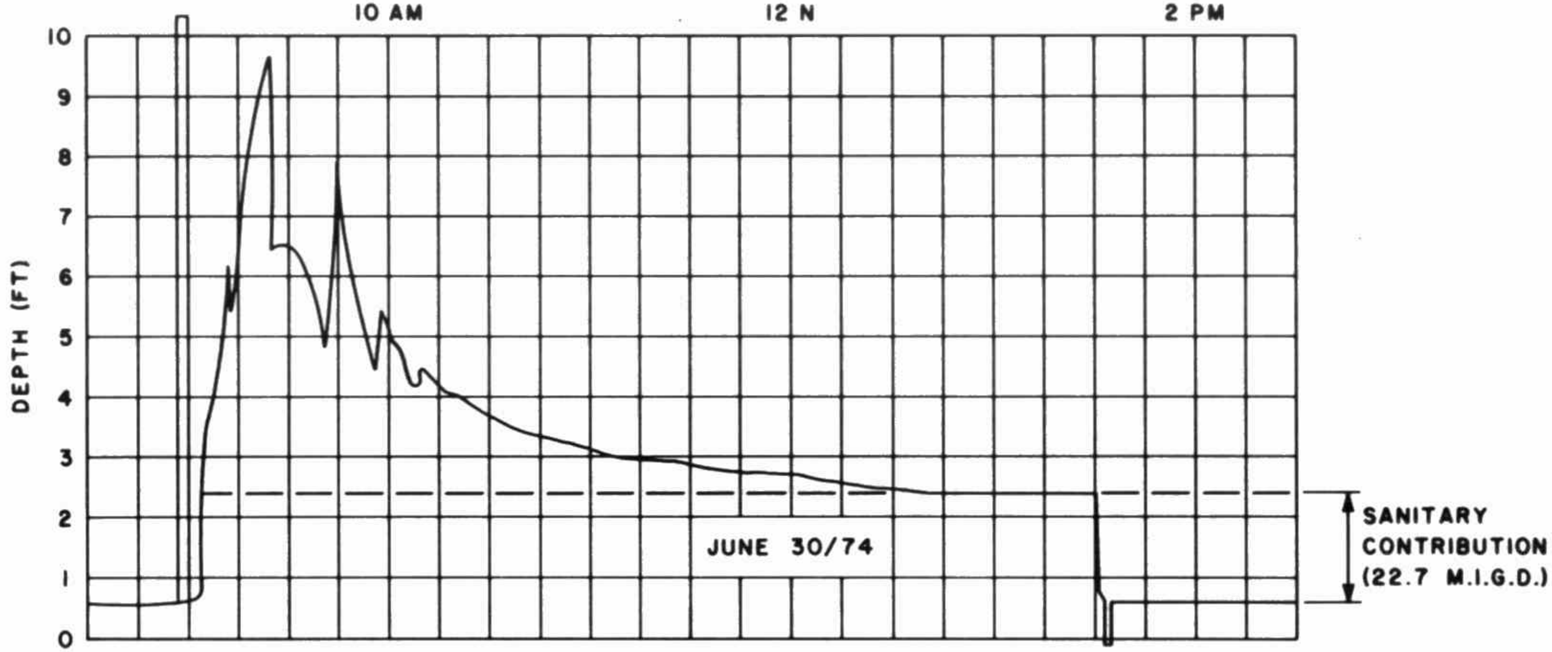


FIGURE 5.3 - TYPICAL STORM FLOW PATTERN OBSERVED BY PROCTOR & REDFERN (1977)

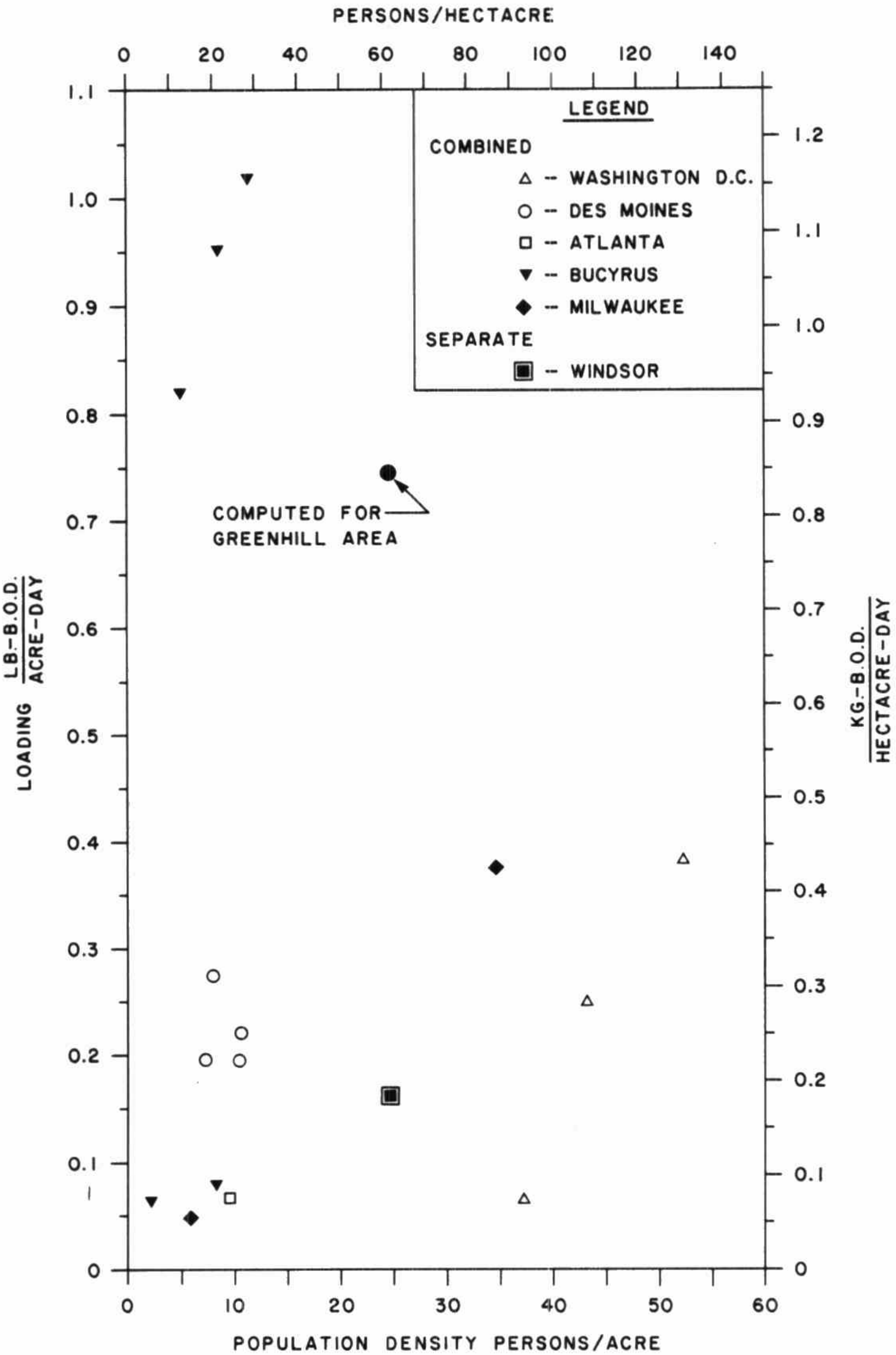


FIGURE 5.4 - COMPARISON OF B.O.D. LOADINGS FROM VARIOUS CITIES (PROCTOR & REDFERN, 1977)

TABLE 5.1a
CHARACTERISTICS OF STORMWATER DISCHARGE POINTS, 1967*

DISCHARGE POINT	DESCRIPTION OF QUALITY
No. 1 Queen Street	Water is turbid. Coliforms 500,000/100 ml. At 4 feet from shore, % volatiles in sediments 11%.
No. 2 Caroline Street	Strong petroleum odour, small patches of oil, sediments are oily, bubbles of gas. Visual evidence of faecal wastes; coliforms 500,000/100 ml.
No. 4 Simcoe Street	Coliforms 5×10^6/100 ml. Gross faecal contamination.
No. 5 James Street	Faecal wastes observed at outfall. Coliforms = 100,000 to 2.2×10^6/100 ml.
No. 6 Catherine Street	Volatiles in sediments 7%; coliforms = 1.5×10^6/100 ml.
No. 7 Ferguson Avenue	Sediments = 54% volatile; coliforms = 300,000/100 ml. Sediments have odour of sanitary sewage.
No. 8 Wellington Street	Water is extremely turbid, containing floating excrement, toilet tissue and other waste material. Gas production within 75 feet of outfall; coliforms = 5×10^6/100 ml.
No. 9 Wentworth Street	Sediments 7% volatile.
No. 10 Hillyard Street	Small patches of scum, odour characteristic of sulfides. Oil slicks appeared due to sediment disturbance. Coliforms 70,000/100 ml.
No. 11 Birch Avenue	Municipal sewerage plus International Harvester discharge. Patches of oil; coliforms 5×10^6/100 ml.
No. 12 Gage Avenue	Dofasco plus municipal sewer outfalls. Rust coloured water; floating sanitary solids. Oil patches were some distance from outfall; sediments 1% volatiles.

CON'T OF TABLE 5.1a

DISCHARGE POINT	DESCRIPTION OF QUALITY
No. 13 Ottawa Street	Municipal outfall. Black appearing water, finely suspended matter. Oil slicks from seepage under skimmer at Dofasco outfall. Temperature of 33^{o}C from cooling water. Sediments 20% volatile.
No. 14 Kenilworth Avenue	Waste matter from raw sewage along the banks; gas bubbles. Objectionable odours; coliforms 5 x 10^6/100 ml.
No. 15 Strathearne Avenue	Gas continually bubbled. Yellow oily scum, 6 inches deep at surface, contained sanitary wastes and other floating debris within 30 feet of outfall.
No. 16 Parkdale Avenue	Cabot Carbon Company discharge to ditch. Noticeable sanitary wastes, floating excrement. Dredge sample showed a sticky amber coloured mass, having a petroleum odour. Phenol = 10 ppb, TP = 13.5 ppm, NH_3 = 262 ppm, NO_3 = 0.52 ppm, Cond = 606 umhos.

* OWRC (1968)

TABLE 5.1b
STORM SEWER NUTRIENT LOADINGS FOR THREE OUTFALLS IN 1967

OUTFALL	AMMONIA (as N) (kg/day)	TOTAL PHOSPHORUS (as P) (kg/day)
Wellington	50	53
Kenilworth	218	30
Strathearne	300	80
TOTALS	568	163

TABLE 5.2
CHARACTERISTICS OF MACLAREN'S (1978) STUDY AREA AND POLLUTANT LOADS

LOCATION	AREA (ACRES)	LAND USE (%) SINGLE FAMILY	MULTIPLE RESIDEN	COMMER- CIAL	INDUS- TRIAL	OPEN SPACE	AVERAGE IMPER- VIOUSNESS (%)	NUMBER OF OVERFLOWS	TOTAL ANNUAL OVERFLOW VOLUME (IN)	AVERAGE AREAL LOADING (LBS/ACRE YR) BOD	SS	ANNUAL LOADING (LBS/YR) BOD	SS
Wellington St. (A)	657	20	6	46	12	16	55	41	7.8	63	440	41,000	290,000
Ferguson St. (B)													
Catharine St. (C)	612	49	7	26	8	10	47	41	6.9	51	330	31,000	200,000
James St. (D)													

1 acre = 0.405 ha

1 lb/acre yr = 1.12 kg/ha yr

1 lb = 0.454 kg

TABLE 5.3
COMPARISON OF MODEL PREDICTIONS AND OBSERVATIONS
(GORE AND STORRIE 1977)

DATE (1976)	RAINFALL VOLUME (m^3)	MEASURED RUN-OFF (m^3)	SIMULATED RUN-OFF (m^3)	PEAK FLOWS MEASURED (L/s)	PEAK FLOWS SIMULATED (L/s)
1976					
Mar. 25	5705	1510	1780	260	325
Apr. 24	47340	23505	22480	900	925
May 6/7	39850	14290	15050	540	540
May 11 a.m.	9395	1398	1675	205	275
May 16 a.m.	2390	630	675	530	540
May 16 p.m.	4895	1340	1495	470	525
July 16	12630	3400	7345	1300	3500
July 20/21	2275	480	520	180	220
July 27	4345	1260	1325	905	960
Sept. 17/18	26000	8280	9392	600	725
Oct 6/7 I	1970	330	420	170	220
II	3115	930	1150	565	735
III	3580	1075	1315	540	670

TABLE 5.4a
POLLUTANT ACCUMULATION IN DUST AND DIRT
(GORE & STORRIE, 1977)

TYPE	LAND USE	ACCUMULATION RATE OF DIRT AND DUST	MG POLLUTANT PER G OF DUST AND DIRT							
		kg /dry day 100m of curb	SS	BOD	COD	SETTLEABLE SOLIDS	N	P	GREASE	COLIFORM MPN/g
1	Single Family Residential	1.1	1000	5.0	40	100	0.48	0.05	1.0	1.3×10^6
2	Multi-Family Residential	3.4	1000	3.6	40	100	0.61	0.05	1.0	2.7×10^6
3	Commercial	4.9	1000	7.7	39	100	0.41	0.07	1.0	1.7×10^6
4	Industrial	6.9	1000	3.0	40	100	0.43	0.03	1.0	1.0×10^6
5	Undeveloped or Park	2.2	1000	5.0	20	100	0.05	0.01	1.0	0

TABLE 5.4b
POLLUTANT CONCENTRATIONS IN STORMWATER
(PROCTOR AND REDFERN, 1977)

LAND USE	ACCUMULATION RATE OF DUST AND DIRT LB./DAY 100 FEET OF GUTTER	POUNDS OF POLLUTANT/100 LBS. OF DUST AND DIRT	
		BOD	SUSP. SOLIDS
Single	1.17	.526	60.92
Multiple	2.14	.337	60.92
Commercial	3.14	.719	58.23
Open	1.50	.50	11.1

SANITARY FLOW

BOD	200 mg/L
SS	367 mg/L

1 lb/d 100 ft of gutter = 1.49 kg/d 100 m of gutter

TABLE 5.5
RUNOFF COEFFICIENT FROM CALIBRATION PROCEDURE
(PROCTOR AND REDFERN, 1977)

LAND USE	AREA (ACRES)	PERCENT IMPERVIOUS	CALIBRATED RUNOFF COEFFICIENT
Residential	2176	38	.44
Multiples	160	75	.71
Institution, Open	321	15	.22
Commercial	193	90	.83

1 acre = 0.405 ha

TABLE 5.6
ESTIMATE OF EXPORT FROM DIFFERENT STUDIES

	HAMILTON COMBINED SEWER OVERFLOWS		BURLINGTON SEPARATE STORM SEWERS		MACLAREN WELLINGTON STREET	FERGUSON-JAMES	GORE & STORRIE	PROCTOR & REDFERN	MARSALEK
	APWA	PLUARG*	APWA	PLUARG*					
BOD	121	81.8	25.8	37.4	63	51	40	140	73
COD							110		110
SS		493		454	440	330	980	390	200
VOLATILE SOLIDS									150
TP	18.7	17.1	4.0	9.32			10.6		2.9
TN	4.5	8.42	0.7	2.87			14.8		2.5
LEAD									0.29

1 lb/acre year = 1.12 kg/ha yr
* Walker and Novak, 1978

TABLE 5.7
APWA DATA FOR THE HAMILTON - BURLINGTON AREA

	HAMILTON	BURLINGTON
Total Urban Area	26,000 acre	13,800 acre
Fully Developed Area	23,500 acre	8,700 acre
Population (1971)	306,000	80,600
Average Population Density	11.7 p/acre	5.84 p/acre
<u>Land Use as % of Total</u>		
Undeveloped	13.6	37.1
Residential	44.5	34
Commercial	7.7	3
Industrial	11.9	3
Other	22.3	27.9
<u>Land Use by Type of Sewer System (%)</u>		
Undeveloped	13.6	33.1
Combined	65.7	0
Separate	20.7	36.2
Unserved	0	26.7
<u>Population Served by Type of Sewer System</u>		
Combined	273,000	63,500
Separate	33,000	17,100
<u>Population Density by Type of Sewer System (p/acre)</u>		
Combined	15.95	12.69
Separate	6.09	4.65
<u>Hydrology (in/yr)</u>		
(a) Annual Precipitation	32	32
(b) Wet Weather Runoff		
Combined Sewer Flow	14.6	13.4
Storm Sewer Flow	10.4	9.6
Combined Sewer and Storm Flow Not Treated	13.7	12.0
(c) Dry Weather Runoff		
Combined Sewer Flow	21.4	17.1
Sanitary Sewer Flow	8.2	8.2
Total	8.3	12.5
(d) Actual Sanitary Sewer Flow Treated	37.7 (55 MIGD)	-

CON'T OF TABLE 5.7

LOADING FACTORS* lb/acre year	HAMILTON DRY WEATHER	HAMILTON WET WEATHER	BURLINGTON DRY WEATHER	BURLINGTON WET WEATHER
(a) BOD				
Combined	990	121	788	27.8
Separate	378	24	289	23.1
TOTAL	843	98	576	25.8
(b) Total Phosphorus				
Combined	149	4.5	118	0.8
Separate	57	0.9	43	0.6
TOTAL	127	3.7	86.5	0.7
(c) Total Nitrogen				
Combined	198	18.7	157	4.3
Separate	76	3.7	58	3.5
TOTAL	168	15.1	115	5.0

1 lb/acre year = 1.12 kg/ha year
1 in = 2.54 cm
1 MIGD = 5.26 10^{-2} m^3/s

* NOTE: Combined and separate loading factors are factors for the respective areas, while total loading factor is average for whole area

5.2 Surface Water Discharges

Surface runoff to Hamilton Harbour enters from two major streams (Redhill Creek 68.9 km^2 (26.6 mi^2) and Grindstone Creek 78.5 km^2 (30.3 mi^2)), three major drains in Burlington (Aldershot Drain 12.7 km^2 (4.9 mi^2); Falcon Creek, 4.1 km^2 (1.6 mi^2); and Rambo-Hager Diversion 22.5 km^2 (8.7 mi^2)) and Cootes Paradise (277 km^2 (107 mi^2)). The basic hydrology of this area was described in Section 2.

The largest portion of the Redhill Creek watershed is dominated by agricultural activity, but the water quality is dominated by urban influences, particularly by stormwater runoff from combined sewer overflow (see the Proctor and Redfern study described above). Routine summer samplings by the Hamilton-Wentworth Regional Laboratory for the past ten years show changes in the various water quality parameters as the creek flows from agricultural to urban areas.

The quantity and quality of water in Grindstone Creek is controlled by agricultural activity except for minor urban influences as it passes through Burlington and for discharges from the Waterdown WWTP. Small drains in Burlington are dominated by urban influences, except for some in the upper regions originating from escarpment woodlands.

Approximately two-thirds of the Cootes Paradise watershed is dominated by agriculture while the remainder is influenced by urban activities including extensive stormwater overflows, some industrial activity and the Dundas WWTP. Two-way exchange between the East Pond of Cootes and the harbour occurs (Kohli, 1979), but the detention time of the East Pond is sufficiently short that little error occurs by assuming that inflows to Cootes immediately enter the harbour.

A summary of some of the data collected by the Hamilton-Wentworth Regional Laboratories for RedHill, Spencer and Ancaster Creeks at various points is shown in Appendix C. Much of the data was

collected as part of the monitoring program for the Hamilton Region Conservation Authority. Other data collected by MOE and by McMaster Experience 1977 Project ("A preliminary material budget for Hamilton Harbour-problem identification") is shown in the Appendix for these creeks and points on Chedoke Creek. The Chedoke Creek samples at the Glen Road Iron Grate and at the Glen Road Overflow reflect points receiving industrial discharges and combined sewer overflows which are important because of the lack of sampling during the water quality survey of Cootes Paradise in 1976.

Table C.6, Appendix C summarizes the data collected for the various creeks by the McMaster Experience 1977 team. Chemical analyses were generally made by the MOE Laboratories in Rexdale, except for BOD, suspended solids, conductivity, chloride and pH. Samples were taken during dry and wet weather flow. No pronounced flow related effects on various parameters were observed, although the sampling frequency - a maximum of four times/storm - precludes an adequate assessment. Assuming that these concentrations are representative of the whole year, loadings are calculated for each point using the average flows of Section 2 and are given in Table 6.1.

An intensive monitoring program was conducted (MOE, 1977) in 1975-1976 for the various streams flowing into Cootes Paradise. Two stations were sampled in the East Pond. Since station C-2 is that furthest from the Cootes-Harbour Channel, it is assumed to be most representative of the East Pond conditions and its values of concentration are those given in Appendix A.3. Assuming that the water quality in 1977 was similiar to 1975-1976, loadings from Cootes to the harbour are calculated (Table 6.1) using the data from Station C-2 and the average annual hydraulic flow into Cootes Paradise. As the average annual detention time of 2.3 days (surface = 160 ha; mean depth = 0.3 m; inflow = 3.7 m^3/s (130 cfs)) is small, Harbour-East Pond exchange is neglected in calculating these loadings.

6.0 ANNUAL AVERAGE LOADINGS TO HAMILTON HARBOUR

6.1 ANNUAL AVERAGE LOADINGS

Average annual loadings to Hamilton Harbour for each discharge point are shown in Table 6.1. The calculations are made for 1977 by multiplying the average annual flow rate, also given in Table 6.1 and adapted from Section 2, by the average annual concentration measured or assumed for that discharge points. All of the 1977 concentration information provided in Table A.1, Appendix A is used for calculation purposes. Due to gaps, it is supplemented where possible by other sources for concentration and/or loading information. In particular, loading information gathered by Environment Canada in 1978 (Table 3.7), is used for supplementing the data base of Appendix A.3.

6.2 ADEQUACY OF DATA BASES USED IN CALCULATING LOADINGS

6.2.1 Total Dissolved Solids

The loadings based on Appendix A.3 for total dissolved solids suggest that the net loading from Stelco is close to zero. This is not possible as it is known that there are significant additions of chlorides to the west side open cut and the northwest outfall. Other operations add dissolved solids to other outfalls. Hence, it is concluded that the data base in Appendix A.3 is inadequate, either because too few samples were collected or because of analytical errors as found in the Environment Canada data set. Thus, the net total dissolved solids loading for Stelco from the Environment Canada data set is provisional. The loadings to the harbour of total dissolved solids are estimated to be 420,000 kg/day.

Another total dissolved solids loading value can be calculated for the industrial and municipal sources from Table 3.8a (Lake Systems Unit, 1973) supplemented by data from Table 6.1. The values are calculated from conductivity measurements of the major sources in 1972 and converted using the relationship, total dissolved solids (mg/L) equals (0.65 conductivity). This relationship, based on electroneutrality balances of Lake Ontario and Hamilton Harbour waters, will change somewhat for the various input sources if the

relative proportions of ions change. In the opinion of this writer, the use of this relationship will provide more consistent information than the data given in Table 6.1, especially since total dissolved solid measurements are not very accurate. Accordingly, it is concluded that the more appropriate loading for total dissolved solids is 607,000 kg/day made up of the following components: municipal - 135,000, industrial - 258,000 (see Table 3.8a), surface streams - 96,000, storm sewers - 7,600, and Cootes Paradise -110,000 kg/day.

6.2.2 Total Nitrogen

The total nitrogen loading estimates in Table 6.1 are higher than those calculated earlier in 1972-1974. This is due partly to inclusion of Cootes Paradise inflows, to a slightly higher export from the Hamilton WWTP, and to a higher value from the industrial sector. The higher values for Stelco are supported by the Environment Canada data. From the sum of the loadings from the WSOC, the NWO and the #3 O.H., Environment Canada data shows a net discharge of 5,000 kg/day for total nitrogen and of 2,000 kg/day for ammonia. This compares quite favourably to the net discharge given in Table 6.1 of 6,000 kg/day of total Kjeldahl of nitrogen and of 1,700 kg/day ammonia. The difference between total Kjeldahl nitrogen and ammonia loadings represents organic nitrogen, a dissolved and/or particulate material, much of which probably settles out in the nearshore areas.

6.2.3 Total Phosphorus

A significant proportion of the total phosphorus is shown to come from the industrial sector, an unexpected result as there are no known sources of phosphorus in the industrial processes. This bias probably results from an inadequate number of samples and associated errors. Based upon these suspicions, the measured industrial input values for phosphorus are rejected and set at zero, giving a total phosphorus budget of 620 kg/day.

6.2.4 Other Substances

No particular difficulties with the loadings estimates for other substances are apparent and hence the figures given in Table 6.1 are considered to be the best available. Two of these substances should be particularly noted. Estimates for total organic carbon have wide confidence limits for streams with low concentrations of total organic carbon, for example 10 mg/L or less. The measurements are made by substracting total inorganic carbon values from total carbon values. As each has measurement errors of about 1 to 2 mg/L, the resultant relative error for total organic carbon is large. For BOD, industrial wastes will probably not exert as much of a biochemical demand in the municipal wastewater or surface streams. Hence, the fraction of total loading represented by industrial should be larger than the figures given in Table 6.1.

6.3 RELATIVE LOADING CONTRIBUTIONS FROM MAJOR SOURCES

Based upon the values given in Table 6.1, the relative fractions of loadings from the five major sources - municipal, industrial, surface streams, Hamilton storm sewers, and Cootes Paradise - are given in Table 6.2. For no substances are the Hamilton storm sewers estimated to be a major contributor to loading. That is, only if the concentration measurements are wrong by an order of magnitude would the storm sewers start to approach even 25% of the total loadings. The only substances for which this size of error could be remotely possible would be total organic carbon, BOD, and suspended solids.

The BOD values could be low by about a factor of 3, caused by the lack of sampling during storm events. Particularly for flow sensitive parameters such as BOD, there will be substantial errors in loading estimates (see Appendix B). However, it is judged that the BOD loadings from the storm sewers could not increase to more than 15% of the total and hence the total loading given in Table 6.1 will not be drastically affected.

A suspended solids concentration of 50 mg/L was used for calculating loading for most storm sewers. As the average observed concentration in that James Street sewer during overflows was 230 mg/L and as the Ontario average of combined sewers during storm events is 220 mg/L, the value in Table 6.2 cannot be in error by more than four times. Increasing the suspended solid loadings by four times leaves the storm sewer portion at only about 4% of the total loadings to the harbour.

A second method to ascertain errors in BOD and suspended solids is to compare the above estimates to the calculated estimates given in Section 5 for various storm sewer catchments. MacLaren's (1977) calculated loadings of 50 kg/day of BOD and 300 of suspended solids from Wellington Street and 40 kg/day of BOD and 250 of suspended solids from Ferguson plus Catharine plus James Street. Comparison with Table 6.1 shows that these values are three times higher for BOD and two times for suspended solids.

Proctor and Redfern (1977) estimate that the export from a combined storm sewer system draining 1170 ha on the mountain and overflowing to Redhill Creek is 960 kg/day of BOD and 2,700 of suspended solids (see Section 5). Compared to the export for Redhill Creek in Table 6.1, BOD is about the same but suspended solids much lower. As Redhill Creek drains other urban areas and a large agricultural area, the BOD loading in Table 6.1 may be somewhat low, perhaps two times, but the suspended solids value appears to be correct. As the surface streams drain non-combined sewer areas there should not be a significant error associated with their values.

Hence, it does not appear that the relative portion in stormwater discharges of the total budgets for BOD and suspended solids will change substantially. As total organic carbon is usually correlated with BOD, then the relative portion of storm water discharges in the budget for total organic carbon is not seriously in error.

The relative importance of combined sewer overflows in municipal discharges is different if presently available unit area export coefficients are used. Table 6.3 shows a summary of data made by M. Zarull (MOE, personal communication) for Hamilton and Burlington. The relative importance of the sewage treatment plant, combined sewer overflows and surface runoff is consistent with the estimates of Table 6.1 for all parameters for Burlington and for total nitrogen and total phosphorus in Hamilton, although the exact fraction is different. However, these unit area estimates suggest that the combined sewer overflow is equal in importance to sewage treatment plant discharges for BOD and suspended solids, a fact not borne out by the estimates of Table 6.1. Hence such estimates based on export coefficients must be treated with caution.

6.4 AVERAGE DETENTION TIME OF POLLUTANTS IN HARBOUR

Based upon Table 6.1 and the hydrology, the average detention time for each substance is given in Table 6.4. The coefficient, α, which relates exchange (E) between the lake and the harbour to hydraulic inflow rate Q, ($E = \alpha Q$) is calculated (Table 6.4) for each substance assuming conservative behaviour for each substance.

If total dissolved solids or chlorides behave approximately conservatively, then α is of the order of 3 to 5. If α equals 4, then the detention time of the conservative substance is 0.2. Hence substances whose detention time or exchange coefficients are higher are quite nonconservative in character. For nitrate plus ammonia (total dissolved nitrogen), the exchange coefficient is approximately 4, suggesting that it acts conservatively. As the total dissolved nitrogen concentrations are substantially higher than algal requirements, only a small amount will be incorporated into biomass. As Snodgrass (1977) found that no nitrogen was released from the harbour in the gaseous form, then denitrification would not be a significant sink and hence washout via exchange would control the total dissolved nitrogen dynamics. As the total nitrogen budget is established with much more confidence than the total dissolved solids budget, then it can be used to establish the exchange rate.

For the period 1967 to 1975, MOE data (MOE, 1975; p. A 28-29) for nitrogen plus ammonia and loadings of total dissolved nitrogen are used to calculate the average annual values for α of Table 6.5. Using surface data for conductivity (MOE 1977; page A-36), the relationship between total dissolved solids and conductivity given above and the total dissolved solids loading of 661,000 kg/day, the monthly variation of α was calculated for 1975 (Table 6.5). These calculations suggest that over a year, α can vary from 2 to 10 with an average of 4.2. They further suggest that α can vary monthly by 2 to 3 times (from 2.3 to 5.7). Calculations of standing stock for 1975 to 1977 are presently incomplete, but based upon total nitrogen, they show similiar seasonal variations. Accordingly, it is concluded that α varies from year to year and seasonally. Inflow at the bottom of a canal and outflow through the surface during stratified conditions suggests that exchange may act as a pump whose rate increases during the late summer.

6.5 CONCLUSIONS

For water quality management of Hamilton Harbour, it is concluded that improved control of municipal and industrial point sources would produce the most significant improvements in water quality. While the deleterious impacts of direct combined sewer overflows cannot be denied, the impact is minimal compared to the point sources. Hence it is concluded that economic and material resources would be more fruitfully expended upon point sources control rather than upon diffuse source control in order to improve the water quality of Hamilton Harbour. If this approach is too costly, then in situ environmental manipulation, such as was tried previously with an aerator or other means such as increasing lake-harbour exchange, becomes attractive. However, Hamilton Harbour eventually acts as a polishing pond for many wastes. Increased lake-harbour exchange will only cause more contaminants to be transported into Lake Ontario where municipal water supply sources could be threatened. A fundamental water quality management question must then be posed: whether it is better to further degrade Lake Ontario waters or whether it is better to leave harbour water quality relatively poor but improve it as far as possible given economic, social and resource pressures and constraints.

TABLE 6.1

ESTIMATED LOADINGS FROM THE VARIOUS SOURCES TO HAMILTON HARBOUR, 1977 in kg/day (See NOTE 24)

AREA	TOTAL PHOSPHORUS	SOLUBLE PHOSPHORUS	TKN	NH_3	NO_3	TOC	COD	BOD5	SS
Hamilton WWTP	326	192	10800(2)	10600	860	7870	20000	5340	11600
Burlington WWTP	45.4	27(4)	510	460	140	1300(4)	3400(4)	910	910
SUB-TOTAL	371	219	11300	11100	1000	9170	23400	6250	12500
Stelco									
East Side	89.2	8.9	178(1)	134	- (18)		18200	4550	29400
North Out.	13.9	1.5	29(1)	22	130(18)		8750	730	3900
#3 O.H.	30.8	4.74	130(1)	95	310	1400(3)	2130	950	2160
NWO	54.6	5.46	9000(1)	4070	500(18)	2180(3)	7070	1040	4970
WSOC	19.6	4.36	1500(1)	1110	470(18)	1800(3)	5690	700	8440
BSPH 1	-32.8	-5.46	-1300(1)	-1000	-580(18)	-2180(3)	-3300(5)	-410	-2730
BSPH 2	- 97.1	-19.4	-3600(1)	-2700	-1820(18)	-7700(3)	-11700	-1840	-8440
SUB-TOTAL	78(23)	0	5940	1730	-(18)	4500(17)	26800	5670	37700
Dofasco									
Lagoon	57.8	6.8	2600(1)	1980	-(18)		12900	5170	26700
Coke Plant	9.8	1.5	1840(1)	1380	310(18)		14600	1940	700
Ottawa St.	68.6	4.2	1450(1)	1090	1630(18)		13300	5530	17500
Boiler House	25.9	2.7	1020(1)	770	-(18)		3270	2070	2690
Bay Water	-123	-15.4	-4620(1)	-3470	-890(18)		-13900	-13600	-8620
SUB-TOTAL	39(23)	0	2290	1750	70(18)	3400(17)	30200	1110	39000
Streams									
Redhill	66.7	13.3	171	77.6	95	1700	4400(9)	1080	7600
Grindstone	29.1	18.4	68	2.4	189	1080	2150	500	3300
Burlington OC	0.73	0.31	11	0.28	88	240	590	120	990
Falcon Cr.	0.36	0.45(8)	3.8(8)	1.1(8)	12(8)	62(8)	140(8)	31(8)	200(8)
Aldershot	1.15	0.41	4.2	0.72	57	150	375	70	310
SUB-TOTAL	98	33	260	82	440	3230	7660	1800	12400

TABLE 6.1 (continued)

ESTIMATED LOADINGS FROM THE VARIOUS SOURCES TO HAMILTON HARBOUR, 1977 in kg/day

AREA	TOTAL PHOSPHORUS	SOLUBLE PHOSPHORUS	TKN	NH_3	NO_3	TOC	COD	BOD5	SS
Hamilton Storm Sewers									
Queen	0.43[8]	0.29[8]	3.8[8]	2.3[8]	0.6[8]	11[8]	41[8]	6.3[8]	28[8]
Caroline	0.21[8]	0.14[8]	1.8[8]	1.1[8]	0.3[8]	5[8]	19[8]	3.0[8]	13[8]
Marshall	0.15[8]	0.10[8]	1.3[8]	0.78[8]	0.2[8]	4[8]	14[8]	2.1[8]	10[8]
James	0.04[9]	0.02[9]	0.69[9]	0.40[9]	0.5[9]	2[9]	7[9]	8.5[19]	62[19]
Cath.-Well.	0.13[9]	0.57[9]	12.0[9]	6.4[9]	4.5[9]	39[9]	140[9]	22.0[9]	190[8]
Wentworth	0.31[9]	0.09[9]	7.4[9]	3.6[9]	5.9[9]	20[9]	100[9]	16.0[9]	150[8]
Birch	1.1[9]	0.88[9]	7.0[9]	4.9[9]	0.2[9]	90[9]	27[9]	33.0[9]	50[8]
Gage	3.0[8]	2.1[8]	27.0[8]	16.2[8]	4.8[8]	75[8]	290[8]	44.0[8]	200[8]
Ottawa	1.1	0.35	2.7	0.75	1.4	79	330	4.8	110
Kenilworth	4.0	2.29	29.5	17.7	2.3	69	260	15.0	190
Strath.	1.1	0.39	14.8	11.0	6.2	56	130	27.0[9]	180[8]
Parkdale	3.5	2.57	28.0	15.9	0.88	75	250	26.6	59
SUB-TOTAL	15	10	140	81	28	530	1600	210	1240
Cootes Paradise	140	19.9	850	130	150	1700	15600	2700	38000
Atmospheric									
GRAND TOTAL	724[23]	280	21000	15000	1700	23000	110000	18000	140000

TABLE 6.1 (continued)

ESTIMATED LOADINGS FROM THE VARIOUS SOURCES TO HAMILTON HARBOUR, 1977 in kg/day

AREA	TDS	Cl	PHENOL	CYANIDE	OIL & GREASE	H^+ (26) x 100 (moles/day)	Fe	Cu	Pb	Zn	Cd
Hamilton WWTP		39700				2.530 (12)	299	18	10.1	86	1.27
Burlington WWTP		5700 (15)				0.568 (12)	7 (22)	1 (22)	0 (6)	5 (22)	0 (6)
SUB-TOTAL	133000 (14)	45400	0 (6)	0 (6)	0 (6)	3.10	306	19	10	91	1.3
Stelco											
East Side	129000	28100 (7)	37.0	72.7	1500	1.40 (8)	20700	31.2	8.9	134.	1.34
North Out.	26200	4600 (7)	1.7	3.6	350	0.146	1000	2.2	1.5	14.	.37
#3 O.H.	78000	15400 (3)	1.2	7.1	470	0.298	240	7.1	2.4	28.	1.19
NWO	92000	19100 (3)	176	792	830	0.216	330	11	5.5	101.	1.37
WSCO	87400	18100 (3)	104	844	300	0.545	650	8.7	8.7	1070	1.09
BSPH 1	-87400	-17200 (3)	-26.5	-11	-270	-0.273	-150	-8.2	-2.7	-24.	-1.34
BSPH 2	-320000	-61000 (3)	-125	-272	-970	-0.971	-560	-58	-9.7	-330	-4.85
SUB-TOTAL	25000 (11,23)	6200	170	1440	2200	1.36	22200	110 (11)	15	990	0 (6)
Dofasco											
Lagoon	118000		7.1	55.4	510	0.068	2920	17	10.2	116	1.7
Coke Plant	27800		6.4	7.0	130	0.094	120	3.8	0.8	5.3	0.38
Ottawa St.	101000		12.3	3.7	330	1.04	11700	25	8.3	29	1.0
Boiler House	51000		10.4	13.2	230	0.108	450	8.2	2.7	11	0.68
Bay Water	-248000		-11.6	-12.3	-1180	-1.21	-1500	-30.8	-15.4	-54	-3.8
SUB-TOTAL	50000 (23)	14000 (13)	24.6	67.	20	0.1	13700	23	6.6	110	0 (6)
Streams											
Redhill	42000 (10)	6260	0.25			0.17	18 (8)	0.83	2.5	1.7	0.42
Grindstone	32000 (10)	11500	0.66			0.17	12.4	0.83	2.5	1.7	0.41
Burling. OC	12000 (10)	4300	0.02			0.015	3.1	0.24	0.71	0.5	0.11
Falcon Cr.	2100 (10)	540 (8)	0.02 (8)			0.003	0.9 (8)	0.04 (8)	0.13 (8)	0.08 (8)	0.02 (8)
Aldershot	7600 (10)	1620	0.08			0.008	4.8	0.27	0.40	0.3	0.07
SUB-TOTAL	96000	24000	1.0	0 (6)	0 (6)	0.40	39	2.2	6.2	4.3	1.0

TABLE 6.1 (continued)

ESTIMATED LOADINGS FROM THE VARIOUS SOURCES TO HAMILTON HARBOUR, 1977 in kg/day

AREA	TDS	Cl	PHENOL	CYANIDE	OIL & GREASE	H^+ (moles/day)	Fe	Cu	Pb	Zn	Cd
Hamilton Storm Sewers											
Queen	190 (10)	25 (8)	0.03			0.5	1.1(8)	0.02(8)	0.04(8)	0.15(8)	0.003(8)
Caroline	90 (10)	12 (8)	0.01			0.3	0.5(8)	0.01(8)	0.02(8)	0.07(8)	0.001(8)
Marshall	70 (10)	8 (8)	0.01			0.2	0.3(8)	0.01(8)	0.01(8)	0.05(8)	0.001(8)
James	69 (10)	12 (8)	0.01			0.2	0.5(8)	0.01(8)	0.02(8)	0.07(8)	0.001(8)
Cath.-Well.	1200 (10)	160 (8)	0.19			3.7	7.3(8)	0.11(8)	0.26(8)	1.0(8)	0.019(8)
Wentworth	1000 (10)	130 (8)	0.15			2.9	5.7(8)	0.09(8)	0.21(8)	0.80(8)	0.015(8)
Birch	360 (10)	43 (8)	0.05			1.0 E-05	1.9(8)	0.03(8)	0.07(8)	0.27(8)	0.005(8)
Gage	1400 (10)	170 (8)	0.20			0.4	7.7(8)	0.12(8)	0.28(8)	1.1(8)	0.02(8)
Ottawa	260 (10)	77	0.026			6.3	38.4	0.09	0.02	3.2	0.004
Kenilworth	1000 (10)	166	0.042			2.4	11.1	0.06	0.39	0.6	0.015
Strath.	1200 (10)	116	0.16			3.5	2.9	0.07	0.11	1.1	0.018
Parkdale	700 (10)	68 (8)	0.14			2.4	2.0	0.08	0.08	0.4	0.008
SUB-TOTAL	7600	990	1.0	1.0 (20)	0 (6)	0.02E-02	80	0.7	1.5	8.8	0.1
Cootes	110000	17000	0 (6)	0	0 (6)	0.34E-02	1100	7.6	10 (8)	23.	1.8(8)
Atmospheric							2 (22)	0.4(22)	1 (22)	6 (22)	0.1(22)
GRAND TOTAL	420000 (23)	110000	200.	1500	2200	5.3E-02	37,400	160	49	1200	4

TABLE 6.1 (continued)

ESTIMATED LOADINGS FROM THE VARIOUS SOURCES TO HAMILTON HARBOUR, 1977 in kg/day

AREA	As	Mn	Cr	Ni	Flow m^3/day
Hamilton WWTP		32.9	38	12.7	253,000
Burlington WWTP		5.0[22]	1 [22]	2.[22]	56,800
SUB-TOTAL	0 [6]	38	39		309,800
Stelco					
East Side	3.12	125	35.7		446,000
North Out.	0.37	12	0.7		72,900
#3 O.H.	0.24	24	2.4		237,000
NWO	0.55	101	2.7		273,000
WSOC	1.31	240	2.2		218,000
BSPH 1	-0.27	-16	-2.7		-273,000
BSPH 2	-0.97	-136	-9.7		-971,000
SUB-TOTAL	4.4	350	31		(2,900)
Dofasco					
Lagoon	2.72	224	10.2		340,000
Coke Plant	0.15	6.8	6.8		75,000
Ottawa St.	0.62	35	45.8		208,000
Boiler House	0.27	12	2.7		136,000
Bay Water	-1.54	-54	-7.7		770,000
SUB-TOTAL	2.2	220	58		(-11,000)
Streams					
Redhill		8.3[8]	1.7[8]	1.7	83,400
Grindstone		8.3	1.7	1.7	82,700
Burlington OC		0.47	0.47	0.47	23,600
Falcon Cr.		0.3[8]	0.08[8]	0.08	4,210
Aldershot		1.2	0.27	0.27	13,400
SUB-TOTAL	0 [6]	19	4.2		207,000

TABLE 6.1 (continued)

ESTIMATED LOADINGS FROM THE VARIOUS SOURCES TO HAMILTON HARBOUR, 1977 in kg/day

AREA	As	Mn	Cr	Ni	Flow m^3/day
Hamilton Storm Sewers					
Queen	0.001[8]	0.23[8]	0.02[8]		563
Caroline	0.001[8]	0.11[8]	0.01[8]		267
Marshall	0.001[8]	0.08[8]	0.01[8]		191
James	0.001[8]	0.11[8]	0.01[8]		267
Cath.-Well.	0.005[8]	1.5[8]	0.11[8]		3,740
Wentworth	0.005[8]	1.2[8]	0.09[8]		2,940
Birch	0.001[8]	0.4[8]	0.03[8]		985
Gage	0.005[8]	1.6[8]	0.12[8]		3,960
Ottawa	0.008	0.38	0.45	0.04	801
Kenilworth	0.006	2.38	0.12	0.06	3,010
Strath.	0.004	0.11	0.11	0.07	3,500
Parkdale	0.002	0.17	0.03	0.02	1,540
SUB-TOTAL	0.04	8.3	1.1		21,800
Cootes	1.8	88	7.0		345,000
Atmospheric				0.2[22]	
GRAND TOTAL	8.4	720	140		884,000 [25]

NOTES TO TABLE 6.1

(1) TKN = 1.33 x (NH_3), this being ratio of NH_3/TKN in Environment Canada data set except for NWO where ratio is 2.2

(2) As the value of TKN is less than the value of NH_3, TKN for Hamilton WWTP is (Ammonia Conc. + 1 mg/L for organic N) x flow.

(3) Environment Canada Data.

(4) COD = 3.7 x BOD, TOC = 1.5 x BOD_5, SP = 0.6 TP, the same ratios as the Hamilton WWTP.

(5) One sample is too high; 12 mg/L is assumed for annual average.

(6) Value is assumed.

(7) Assumes same concentration as in the influent.

(8) Assumes average concentration of surface streams or of storm sewers (excluding Ottawa St.)

(9) Poulton's data for concentration in 1977 is used.

(10) TDS = 0.65 x Conductivity (After Kohli, 1977) plus note !8 where relevant.

(11) Net Loading from Environment Canada Data is used, as net calculated from this table is low. Hence, this net loading figure excludes contributions from North Outfall and East Side Lagoon.

(12) pH of 7.0 is representative of measurements made by Hamilton Regional Laboratories for Hamilton WWTP. Same value is assumed for Burlington WWTP. Note, Hamilton city water averages approximately 8.2; treatment with alum reduces this pH to 7.8.

(13) Ratio of Cl/TDS is assumed to be same for Stelco and Dofasco.

(14) Estimated by Kohli, 1977. Also, his value for industrial loadings of 232,000 kg/day is approximately 3X value of this table.

(15) Conc. of 100 mg/L is representative of recent data .

(16) Concentration of 5 mg/L is assumed.

(17) From Table 3.9. These values appear valid, as recent Environment Canada Data(3) shows a good comparison except for WSOC.

(18) From Table 3.9. Net Loading is for both industries as Ottawa St. includes all discharge points to Ottawa St. Slip.

(19) Concentration data gathered as a part of MacLaren's study.

(20) Average concentration of 0.05 mg/L is assumed for all storm sewers.

(21) Average concentration for 1971-1975 is used.

(22) Concentration estimates of 1975 are used. (MOE, 1977b Table 3, p. C-24).

(23) These figures are rejected and others substituted as indicated in text.

(24) Generally 3-figure accuracy is maintained in the estimates and sub-totals; where the data is coarse and for total values only 2 figure accuracy is maintained.

(25) Industrial Net Flows are assumed to be zero.

(26) Budget for H^+, not total H, as hydrogen is also associated with such molecules as carbonate. Loadings are in moles per day.

TABLE 6.2b
PERCENTAGE OF INPUTS TO HARBOUR FROM MAJOR SOURCES

	CYANIDE	OIL & GREASE	H^{+}*	Fe	Cu	Pb	Zn	As	Mn	Cr
Municipal	0	0	58	0.8	11	20	7	0	4	27
Industrial	100	100	28	96	83	44	90	80	80	64
Streams	0	0	8	0	1	13	0.4	0	3	3
Hamilton Storm Sewers	0	0	0	0	0.3	3	0.7	0.5	1	1
Cootes Paradise	0	0	6	3	5	20	2	20	12	5

* Budget for H^{+}, not total H

TABLE 6.2a

PERCENTAGE OF INPUTS TO HARBOUR FROM MAJOR SOURCES

	TOTAL P	SOLUBLE P	TKN	NH_3	NO_3	TOC	COD	BOD_5	SS	TDS	Cl	PHENOL
Municipal	52	79	54	74	59	40	22	35	9	32	41	0
Industrial	14	0	40	24	4	35	54	38	55	18	19	99
Streams	14	12	1	0.5	26	14	7	10	9	22	22	0.5
Hamilton Storm Sewers	2	4	0.6	0.5	2	2	2	3	1	2	1	0.5
Cootes Paradise	18	5	4	0.8	9	9	15	14	26	26	17	0

TABLE 6.3

COMPARISON OF ANNUAL LOADINGS FROM HAMILTON AND BURLINGTON USING UNIT LOAD CALCULATIONS OF OTHERS

1. Areal Loadings for Hamilton (lb/acre-year)

PARAMETER	EFFLUENT WWTP	COMBINED SEWER OVERFLOW		SURFACE RUNOFF	
	MOE (2)	APWA (1)	MOE (2)	APWA (1)	MOE (2)
BOD	119	121	81.8	24.1	40.6
SS	176	-	470	-	493
TN	126	18.7	17.1	3.7	10.2
TP	7.00	4.5	2.74	0.9	1.01

2. Areal Loadings for Burlington (lb/acre-year)

PARAMETER	EFFLUENT WWTP	SURFACE RUNOFF	
	MOE (2)	APWA (1)	MOE (2)
BOD	70.8	25.8	37.4
SS	95.7	-	454
TN	97.9	4.0	9.21
TP	12.8	0.7	0.93

1. American Public Works Association, 1969.

2. Waller and Novak, 1978.

1 lb/acre-year = 1.121 kg/ha-year

TABLE 6.4

ESTIMATED RETENTION TIME OF SUBSTANCES IN HAMILTON HARBOUR

PARAMETER	AVERAGE INFLOW CONCENTRATION	AVERAGE HARBOUR CONCENTRATION (YEAR, SOURCE)	AVERAGE LAKE CONCENTRATION (YEAR, SOURCE)	DETENTION TIME OF PARAMETER	α
TP	0.820 mg/L	0.075 (1975; A-31, MOE, 1977)	0.03	0.09	10
SP	0.320	0.011 (1975; A-31, MOE, 1977)	0.01	0.033	-
TKN	24.6	2.05 (1975; A-30, MOE, 1977)		0.08	-
NH_3	1.9	1.6 (1975; A-30, MOE, 1977)	0.3 (1969; A-36, MOE, 1977)	0.8	-
NO_3	16.9	0.93 (1975; A-30, MOE, 1977)	0.06 (1969; A-36, MOE, 1977)	0.05	-
TN	26.0	3.6 (TKN + NO_3)	0.4	0.13	7
TOC	26	4			
COD	120	20 (1976; B-43, MOE, 1978)	2	0.17	5.6
BOD_5	20	4 (1976; B-43, MOE, 1978)	1	0.2	5.7
SS	160	-	-	-	-
TDS	480	266 (1975; Kohli, 1977)	220 (1975; Kohli, 1977)	0.54	4.8
Cl	124	61 (1975; A-36, MOE, 1977)	31 (1969; A-36, MOE 1971)	0.47	2.3
PHENOL	0.23	0.001	N.D.	0.004	230
CYANIDE	1.7	0.01	N.D.	0.006	170
OIL & GREASE	2.5	0.1	N.D.	0.04	24
H^+	6.0×10^{-8} Moles/L (pH = 7.22)	1.58×10^{-8} (pH = 7.8) (1973; A-23, MOE, 1974)	6.3×10^{-9} (pH = 8.2)	0.26	4.7

TABLE 6.4 (continued)

PARAMETER	AVERAGE INFLOW CONCENTRATION	AVERAGE HARBOUR CONCENTRATION (YEAR, SOURCE)	AVERAGE LAKE CONCENTRATION (YEAR, SOURCE)	DETENTION TIME OF MATERIAL	α
Fe	47	0.3 (1976; C-9, MOE, 1978)	N.D.	0.007	150
Cu	0.18	0.02 (1975; A-33, MOE, 1977)	N.D.	0.1	10
Pb	0.055	0.09 (1976; C-9, MOE, 1978)	N.D.	1.6	-
Zn	1.4	0.1 (1976; C-7, MOE, 1978)	N.D.	0.07	14
Cd	0.005	0.01	N.D.	-	-
As	0.01	0.001	N.D.	0.1	9
Mn	0.8	0.09 (1975; A-33, MOE, 1977)	N.D.	0.1	20
Cr	0.16	0.02	N.D.	0.1	7
Ni	-	0.02	N.D.	-	-

Notes:

1. Based on average annual inflow of 884,000 m^3/day from all sources
2. C_{in} = average inflow concentration, C_h = average harbour concentration, C_l = average lake concentration.
3. Detention time of substance, $\tau_s = C_h/C_{in} * \tau w$; τw = hydraulic detention time = Volume of water/hydraulic inflow rate.
4. α is given by E = Q, where E is average annual lake exchange rate and Q is average annual inflow rate to harbour. $\alpha = (C_{in} - C_h)/(C_l - C_h)$.
5. For calculation of τ_s and , the detection limit is assumed as the concentration.

TABLE 6.5
ESTIMATED ANNUAL AND SEASONAL VARIATION IN THE EXCHANGE COEFFICIENT

(a) Annual Variations of α, based upon total dissolved nitrogen

YEAR	α
1967	10.2
1968	2.5
1969	2.6
1970	1.2
1971	1.5
1972	4.9
1974	6.2
1975	4.9

(b) Seasonal Variation of α, based upon total dissolved solids

DATE	SURFACE MEAN CONDUCTIVITY	ESTIMATED TDS	CALCULATED α
April 22	538	350	2.6
May 7	554	360	2.3
May 29	525	340	2.9
June 11	528	343	2.8
August 13	470	306	4.4
September 9	449	209	5.7

NOTES:

1. For Lake Ontario, TDS = 220
2. For 32 days in September-October, Kohli's data for average Harbour TDS is 266 mg/L, giving a value for α of 6.8. Hence some differences may be expected based upon use of surface means.
3. TDS Loading = 607,000 kg/day.
4. α is calculated from $\alpha = \frac{C_{IN} - C_{HARBOR}}{C_{LAKE} - C_{HARBOR}}$

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APPENDICES

INTRODUCTION

These appendices present other data gathered on Hamilton Harbour in 1977, a summary of previous data gathered on various streams by the Regional Conservation Authority, some typical time profiles measured on the James Street outfall, and a few different models for calculating annual loadings to water bodies.

Appendix A.1 shows the variation of BOD, SS, TOC, conductivity, chloride versus height of flow and time for a summer storm of August 8, 1977 at the James Street overflow. The height of flow is that entering a manhole at Guise Street. The overflow is a broadcrested weir. When the height of flow entering the manhole was greater than approximately 6", the sewer would overflow, as, at the time of sampling, the manual bypass to the cross-town interceptor was only open to a depth of some 3 inches. Other data gathered is given in Table A.1. Overall it shows that concentrations of BOD and SS, being erodable materials, increase with increasing flow (increased height) while conductivity and chlorides decrease with increasing flows. The implications of significant concentration-flow relationships are described in Appendix A.2 "Method of calculating loadings to water bodies".

Appendix A.3 is a tabulation of concentrations measured in the various inflows to the Harbour during the period 1971-1977 for the following elements (in order): TP, SP, NH_3, TKN, NO_3, NO_2, COD, BOD_5, Filtered TOC, TOC, HCN, Phenol, Ether Sol., Cl, Cond., pH, SS, Turbidity, Colour, As, Cd, Cr, Cu, Fe, Pb, Mn, Ni, Zn.

Appendix B presents a summary of the work of an Experience '77 team which examined temporal variations of inputs to various slips in Hamilton Harbour. It was directed by Dr. Donald Poulton of the Lake Systems Group, Water Resources Branch, MOE. The emphasis in this work was on the measurement of the actual water quality of discharges to the Harbour over a six hour time frame. The data

shows pronounced variablity resulting from variable inputs and variable internal Harbour motions (e.g. see conductivity traces in Fig. B.1-B.6). Average values for the measurements are included in Table 3.1 of the report and were used for calculations of loadings to the Harbour. The loadings calculated by Poulton are not used as they were based on flows measured in a slip, values which this writer judged to represent a mixture of both Harbour flows as well as storm discharge flows.

Appendix C presents tables of data which summarize water quality information gathered for various streams under the auspices of the Hamilton Region Conservation Authority since 1967, and data gathered by the Experience '77 group under W. J. Snodgrass for Chedoke Creek. This information is particularly helpful to those interested in changes in water quality in streams in the Hamilton Harbour watershed.

APPENDIX A

A.1 - Graphical and tabulated summary of flow and concentration in James Street Sewer, August 8, 1977.

A.2 - Methods of calculating loadings to water bodies.

A.3 - Concentrations in streams flowing to Hamilton Harbour for the period 1971 to 1977.

APPENDIX A.1
GRAPHICAL AND TABULATED SUMMARY OF FLOW AND CONCENTRATION IN JAMES STREET SEWER AUGUST 8, 1977

TABLE A.1 WATER QUALITY MEASUREMENTS AT JAMES ST. OUTFALL

Date	Time	BOD (mg/l)	SS (mg/l)	Cond. μS/cm	Cl (mg/l)	TP (mg/l)	TOC (mg/l)	pH	Water Depth (in)
June 29, 1977	7:30 am	32	37	*	*	1.4	36	*	3
	8:00	37	63			2.7	31		3
	8:30	77	80			1.9	41		3
	9:00	60	68			2.4	29		3
	9:30	87	78			0.35	39		3
	10:00	57	80			0.35	36		4
	10:30	68	60			0.75	33		4
	11:00	57	130			0.68	55		4
	11:30	93	94			1.7	40		6
	12:00 pm	105	160			0.15	34		8
	12:30	54	56			1.9	32		6
July 6, 1977	10:29 am	46	280	*	*	0.10	23	*	19
	10:42	36	180			<.01	13		16
	10:50	36	130			.61	17		14
	11:00	32	110			.74	14		10
	11:10	26	90			.04	21		5
	11:20	38	70			.26	15		3
	11:30	42	80			1.2	17		3
	11:40	49	73			1.1	18		3
	11:50	33	110			.61	16		6
	12:00 pm	32	180			.09	-		8
	12:10	35	140			.48	14		7
	12:20	35	120			.80	17		5
	12:30	80	120			3.9	41		4
	12:40	115	130			5.7	33		3
	12:50	100	110			6.7	34		3
	1:00	86	88			4.6	28		3

TABLE A.1 Cont'd

Date	Time	BOD (mg/l)	SS (mg/L)	Cond. μS/cm	Cl (mg/l)	TP (mg/l)	TOC (mg/l)	pH	Water Depth (in)
July 6, 1977	2:20 pm	79	86	940	94	3.5	32	*	3
	2:50	65	47	890	112	2.0	24		3
	4:45	68	54	920	108	3.2	35		3
	4:50	69	42	995	96	0.4	32		5
	4:55	61	22	945	115	1.6	21		8
	5:00	34	192	200	14	0.5	14		22
	5:05	28	350	120	4.6	N.D.	12		36
	5:10	24	280	120	4.4	N.D.	10		30
	5:15	27	160	120	7.0	N.D.	10		18
	5:20	22	160	148	8.2	.56	14		12
	5:25	19	111	179	12	.26	10		7
	5:30	27	100	230	17	.56	13		7
	5:35	28	88	290	23	.76	12		7
	5:40	28	72	375	23	.21	12		5
	5:45	29	47	343	32	.36	14		5
	5:50	16	42	328	27	.51	12		4
	6:05	34	45	460	43	N.D.	17		3
	6:20	34	35	495	40	.46	18		3
	8:00	81	87	420	52	3.7	23		5
	8:30	41	55	525	38	.91	15		4
July 7, 1977	2:40 am	93	260	402	56	.91	20	*	5
	2:45	64	285	287	30	.21	17		10
	2:50	35	190	138	13	2.0	12		14
	2:55	37	160	148	15	.10	10		13
	3:00	28	130	124	13	.06	11		9
	3:10	30	90	162	17	.25	11		4
	3:20	39	72	234	28	.36	15		4

TABLE A.1 Cont'd

Date	Time	BOD (mg/l)	SS (mg/l)	Cond. (μS/cm)	Cl (mg/l)	TP (mg/l)	TOC (mg/l)	pH	Water Depth (in)
July 27, 1977	1:00 pm	130	98	780	76	*	65	7.7	*
	1:30	150	98	1120	115		67	7.9	
	2:00	89	150	880	89		43	7.6	
	2:30	39	37	790	78		31	7.6	
	3:00	57	25	850	100		32	7.9	
	3:30	75	130	900	82		43	7.0	
	4:00	46	82	540	52		13	7.4	
Aug. 8, 1977	1:18 pm	24	184	93	8.8	*	13	7.8	26
	1:20	21	228	80	7.6		8	7.6	26
	1:27	19	207	96	7.6		7	7.4	21
	1:29	33	156	100	9.4		7	7.4	17
	1:33	33	158	113	12.9		13	7.4	10
	1:38	21	117	141	16.5		12	7.3	7
	1:43	25	108	173	20.		16	7.3	2
	1:48	20	94	152	16.3		15	7.3	4
	1:51	24	110	134	15.8		14	7.3	8
	1:53	19	123	134	19		13	7.2	-
	1:54	13	83	151	15		18	7.2	6
	1:58	33	48	180	22		13	7.1	3

TABLE A. 1 Cont'd

Date	Time	BOD (mg/l)	SS (mg/l)	Cond. (μS/cm)	Cl (mg/l)	TP (mg/l)	TOC (mg/l)	pH	Water Depth (in)
Nov. 7, 1977	10:30 am	64	85	*	*	*	*	*	3.5
	11:00	24	49						4
	11:30	31	47						4.5
	12:00 pm	36	52						4
	2:30	41	67						3.5
	2:45	22	24						4
	3:00	16	33						4
	8:00	66	48						3
	10:00	77	79						3
Nov. 10, 1977	12:30 pm	26	128						3
	1:00	30	208						3.5
	1:30	51	248						3.5
	2:00	43	47						3.5
	2:30	39	40						3

* Not measured during this storm.

Comments:

1. Data for June 29 (morning flows) and July 27 (afternoon flows) are for non event periods and are indicative of the combined sewer water quality which is intercepted and enters regional interceptor sewer.

2. July 6 data is for two major thunderstorms and one minor. The storms started respectively at 10:10 am, 11:50 am. and 4:55 pm. The July 7 storm commenced at 2:30 pm. Hence water quality was obtained at the ~~peak of the first hydrograph, but for the whole hydrograph of the last 3 storms~~. FOR ALL OF THE FIRST [illegible] BOT [illegible] LAST TWO STORMS

3. On Aug. 8, light showers occurred after 12:00. At 12:50 pm, the intense rain started, stopping at 1:20. A light mist was observed from 1:20 on. Rainfall records (RBG) indicate 10.8 mm from 12:00-1:00 pm, 5.8 mm from 1:00 to 2:00 and 0.2 mm from 2:00 to 3:00.

4. The November storms represent day-long rainfalls, much less intense than the summer storms.

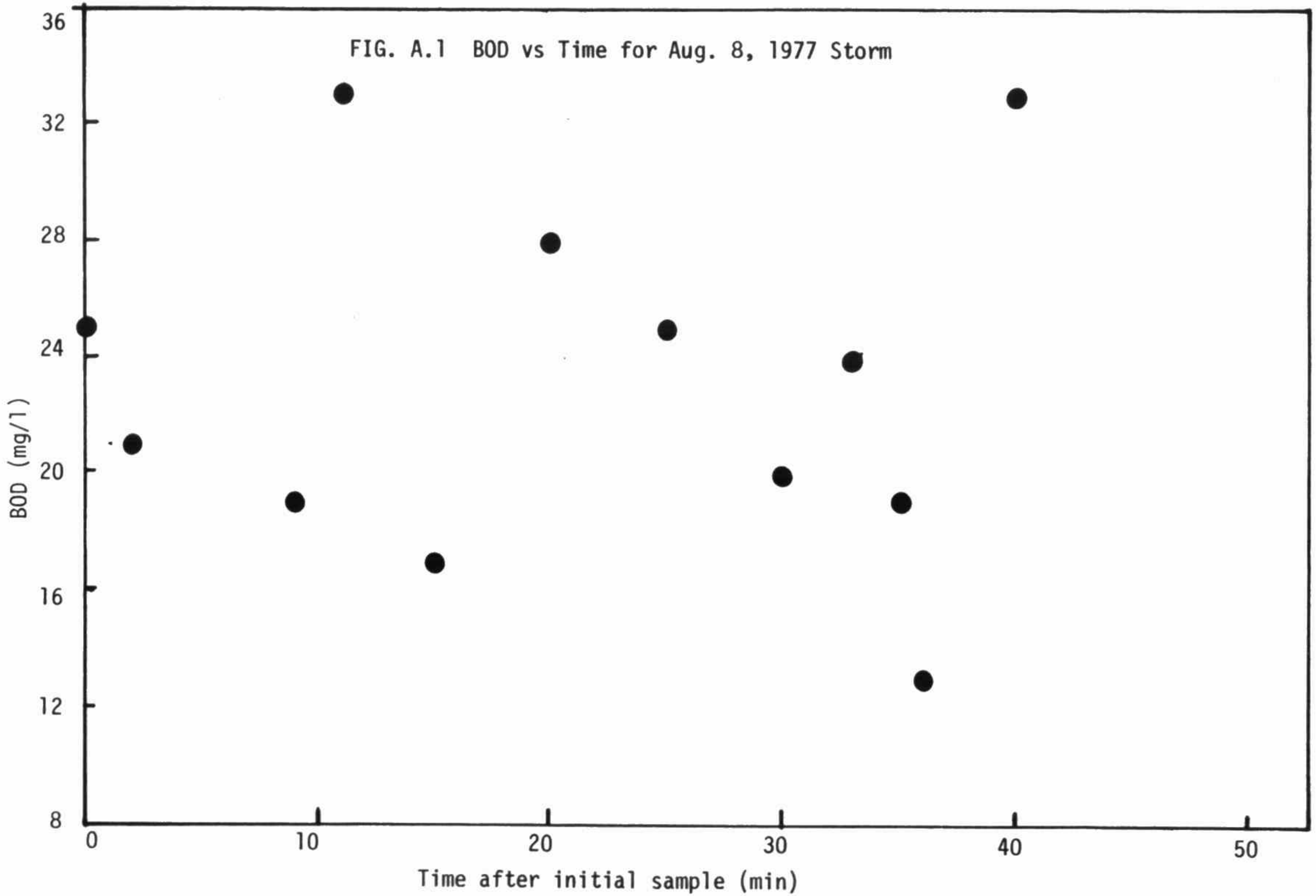


FIG. A.1 BOD vs Time for Aug. 8, 1977 Storm

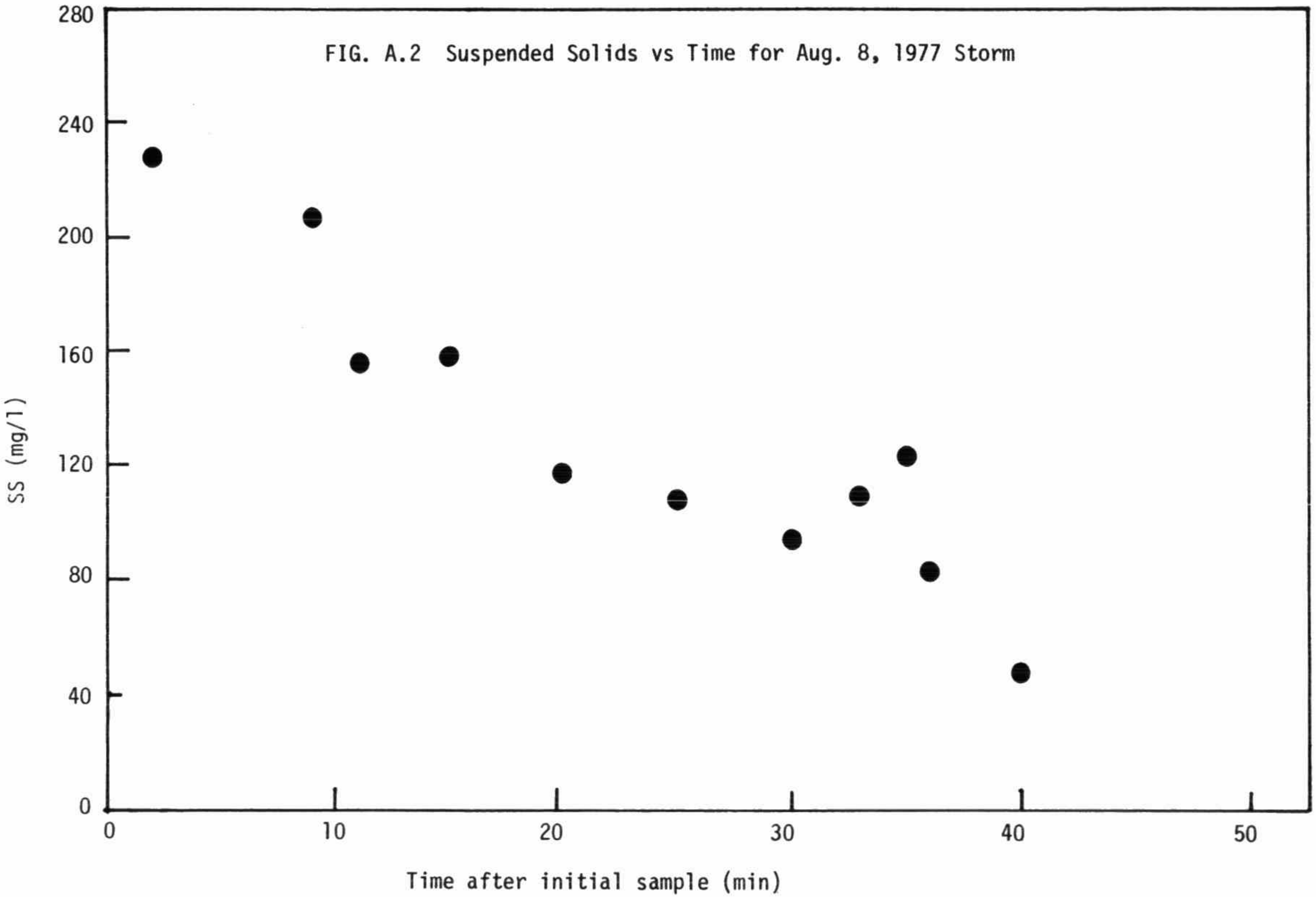


FIG. A.2 Suspended Solids vs Time for Aug. 8, 1977 Storm

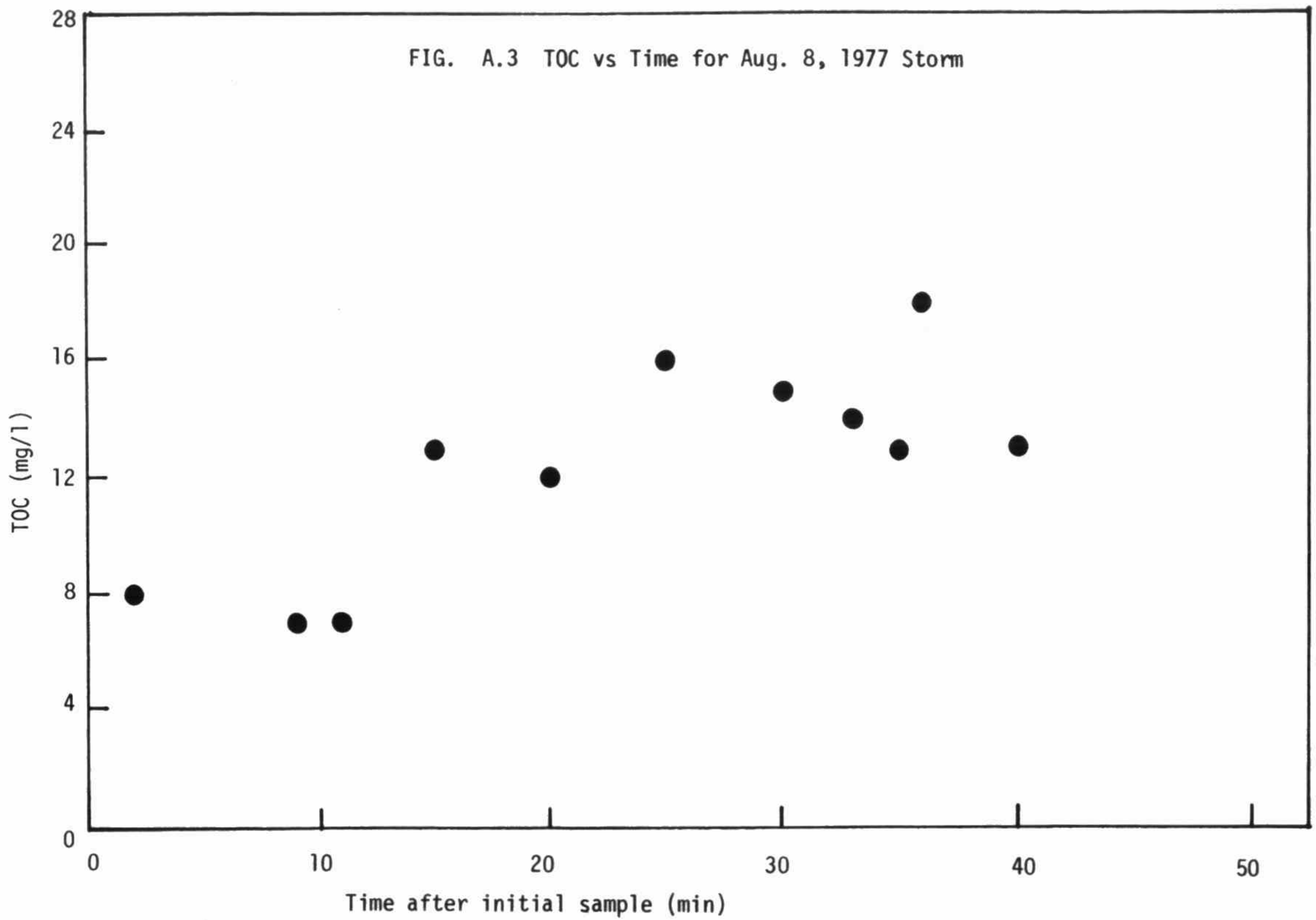


FIG. A.3 TOC vs Time for Aug. 8, 1977 Storm

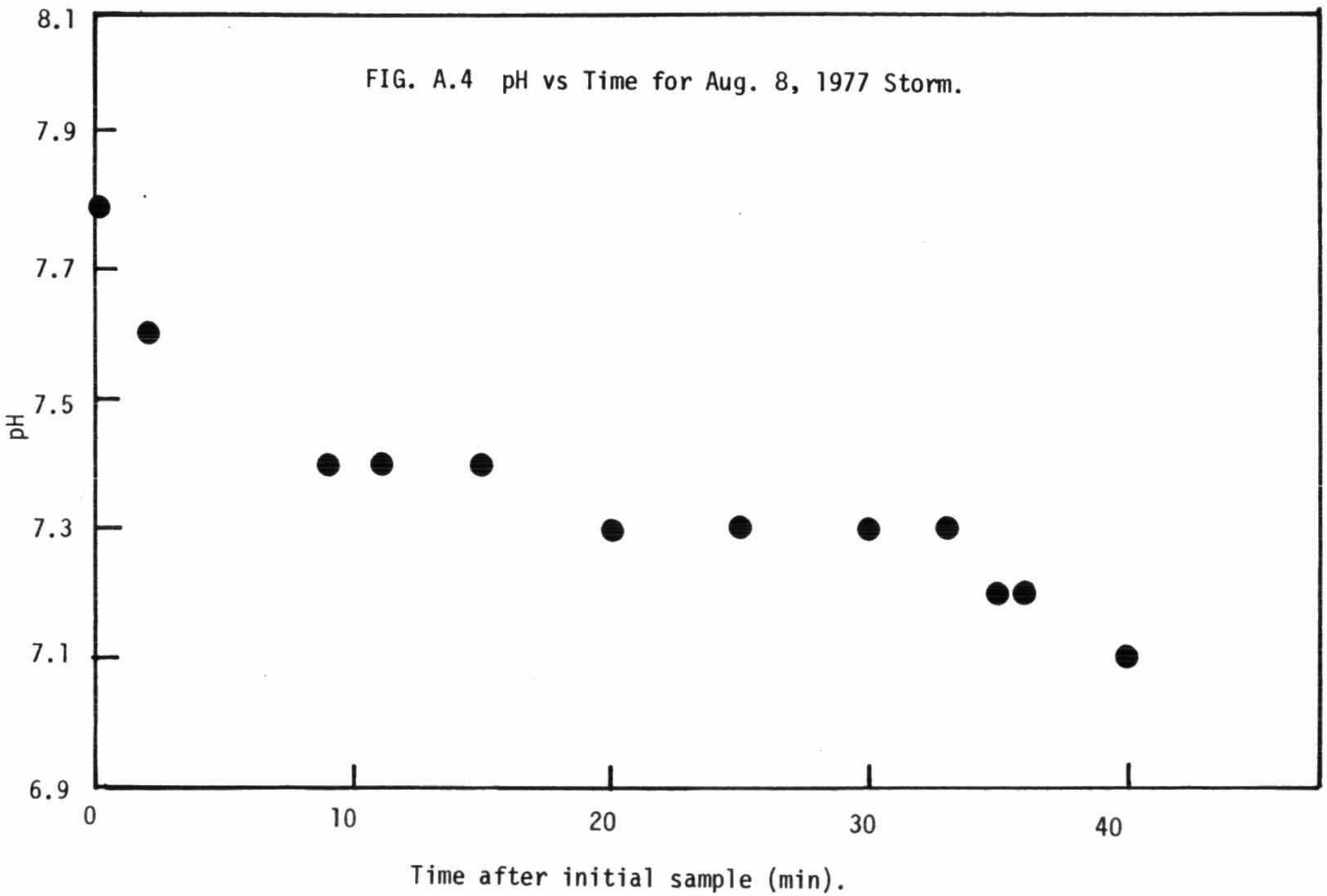
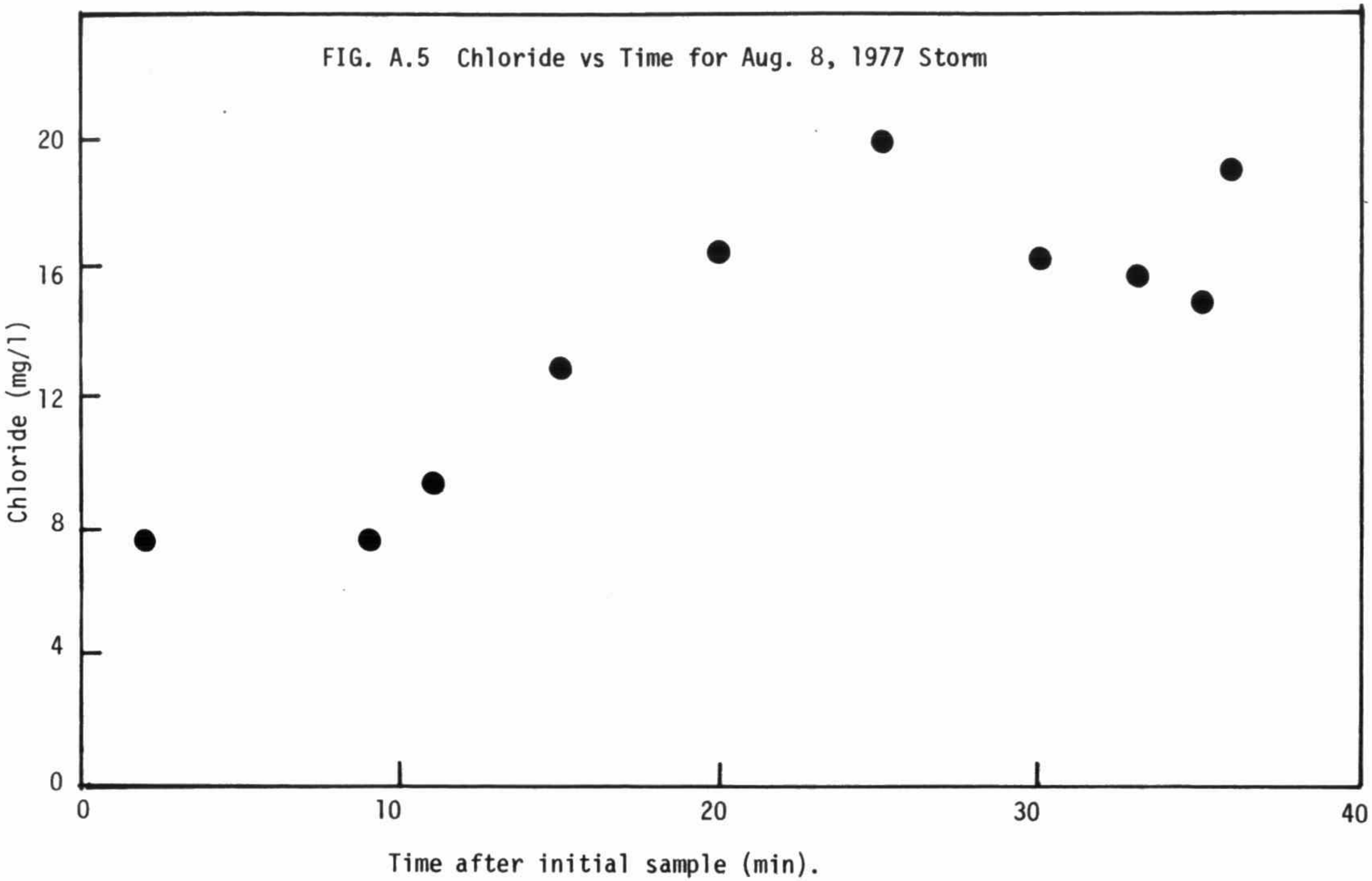


FIG. A.4 pH vs Time for Aug. 8, 1977 Storm.

FIG. A.5 Chloride vs Time for Aug. 8, 1977 Storm



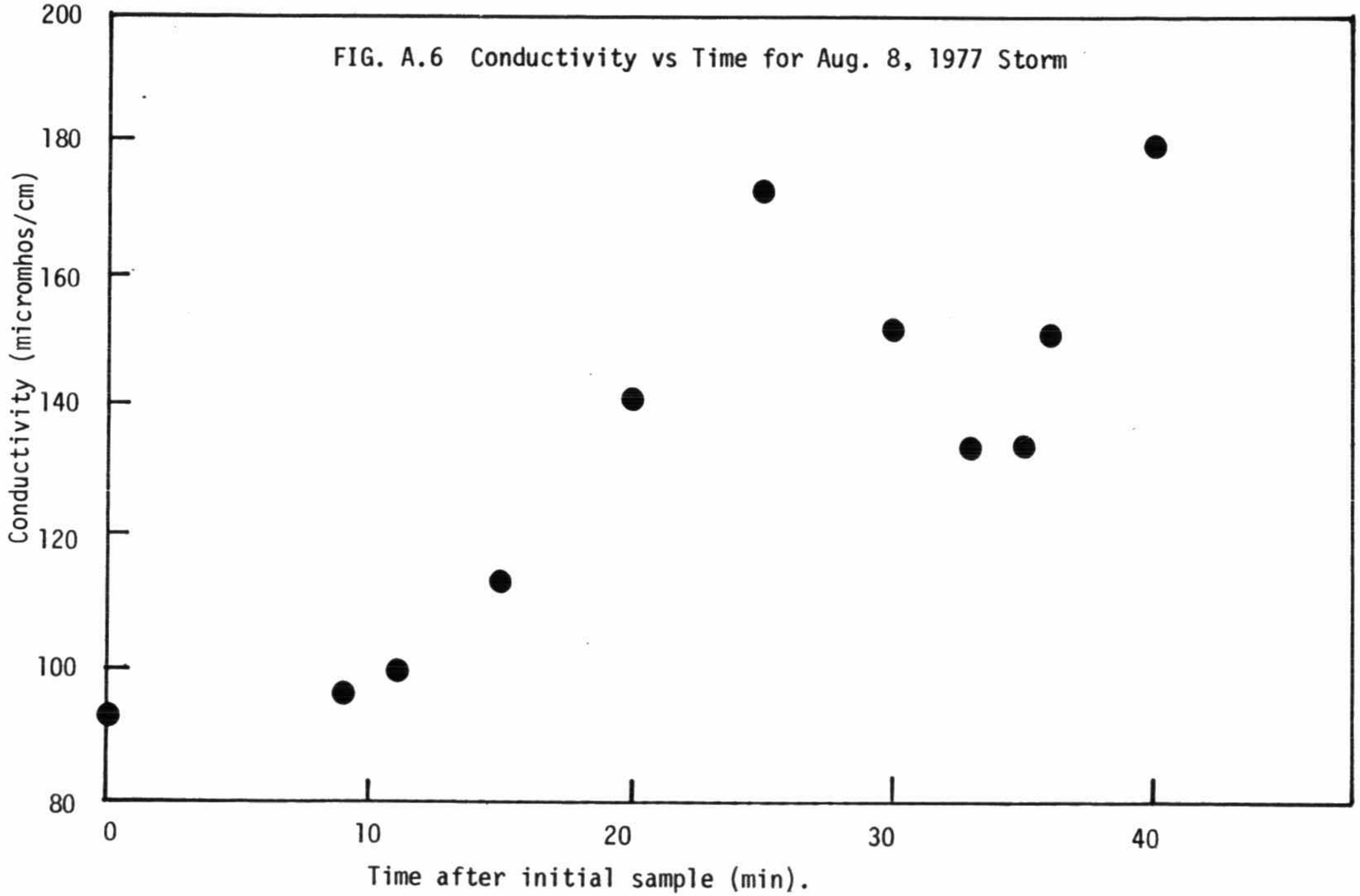


FIG. A.6 Conductivity vs Time for Aug. 8, 1977 Storm

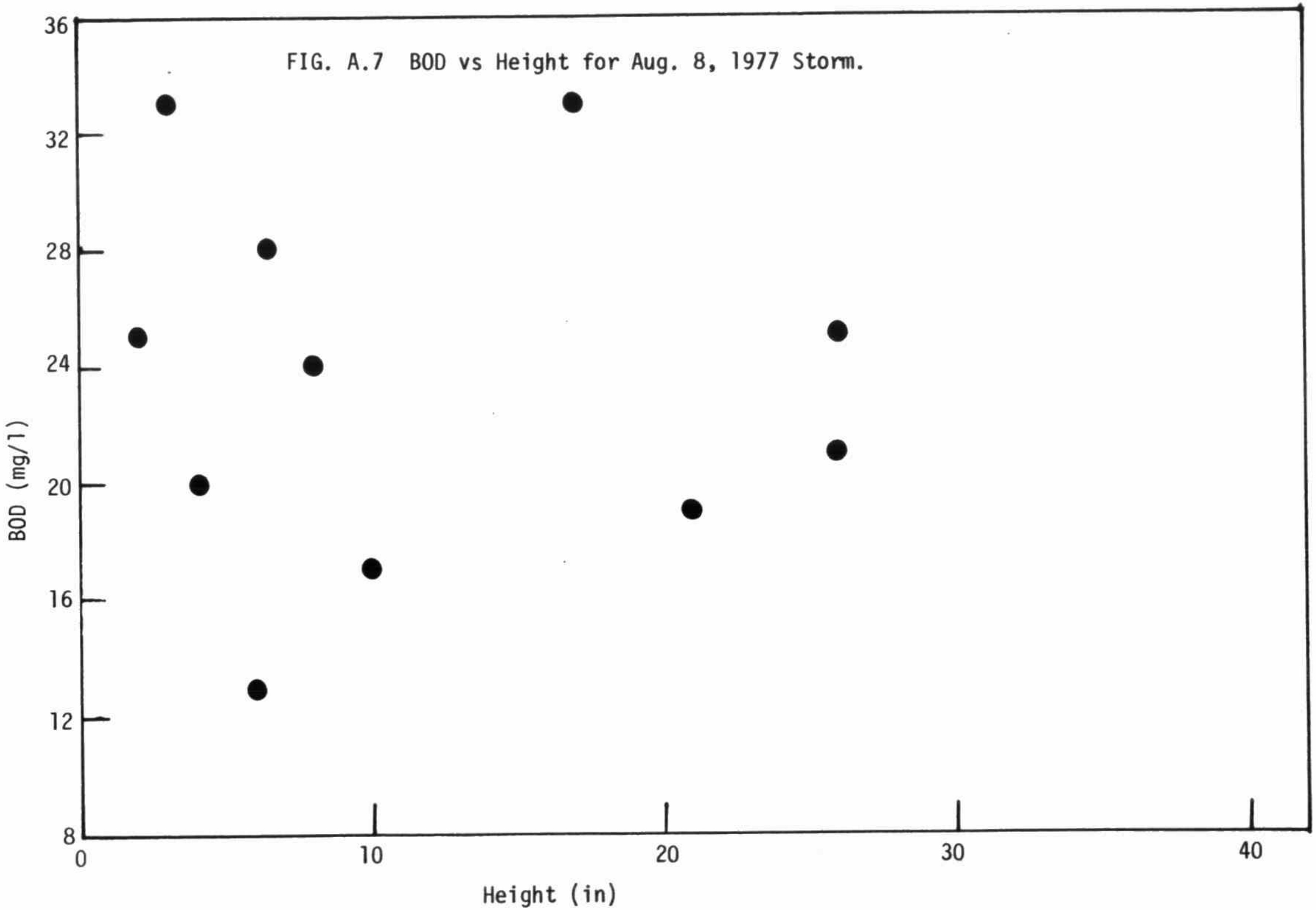


FIG. A.7 BOD vs Height for Aug. 8, 1977 Storm.

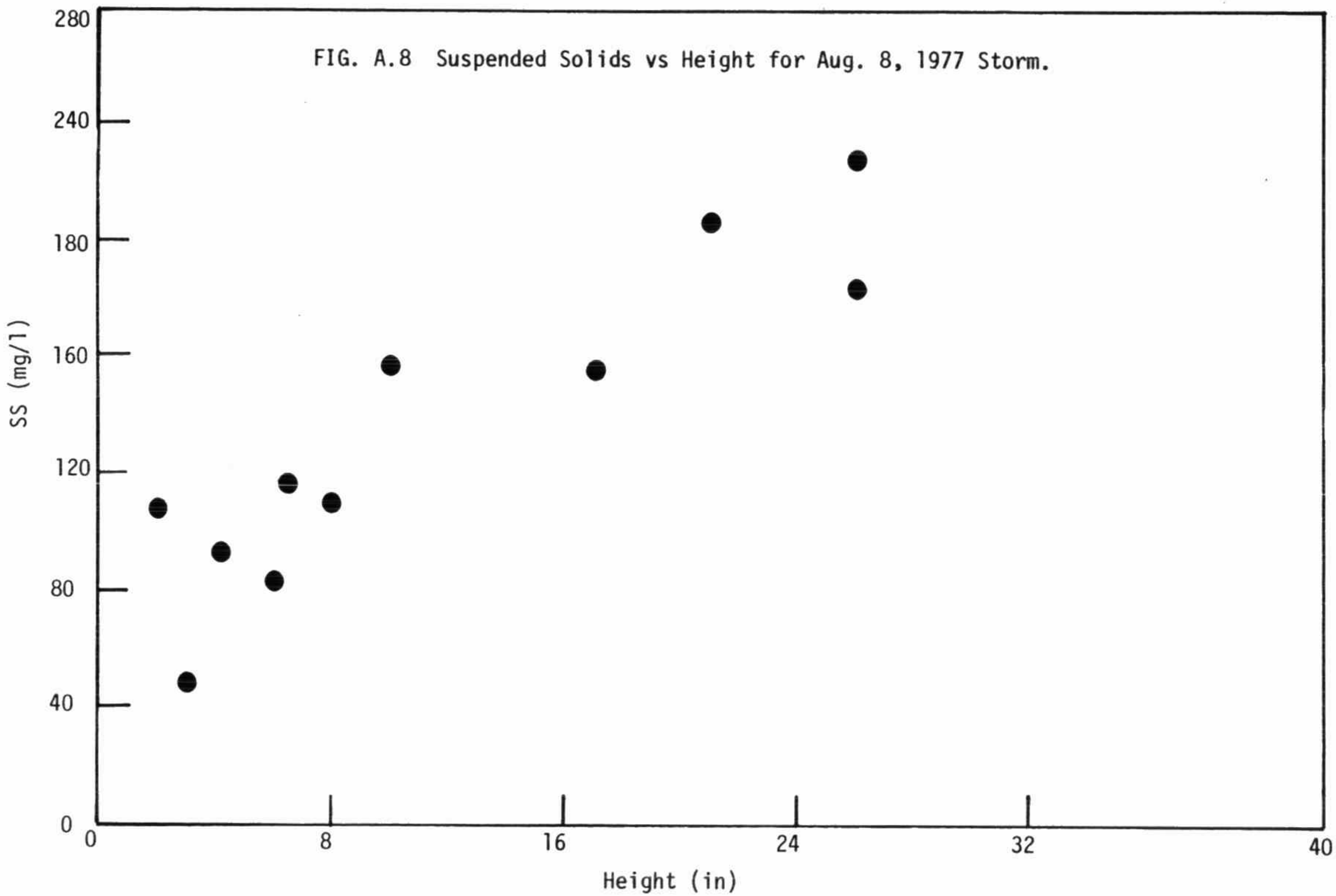


FIG. A.8 Suspended Solids vs Height for Aug. 8, 1977 Storm.

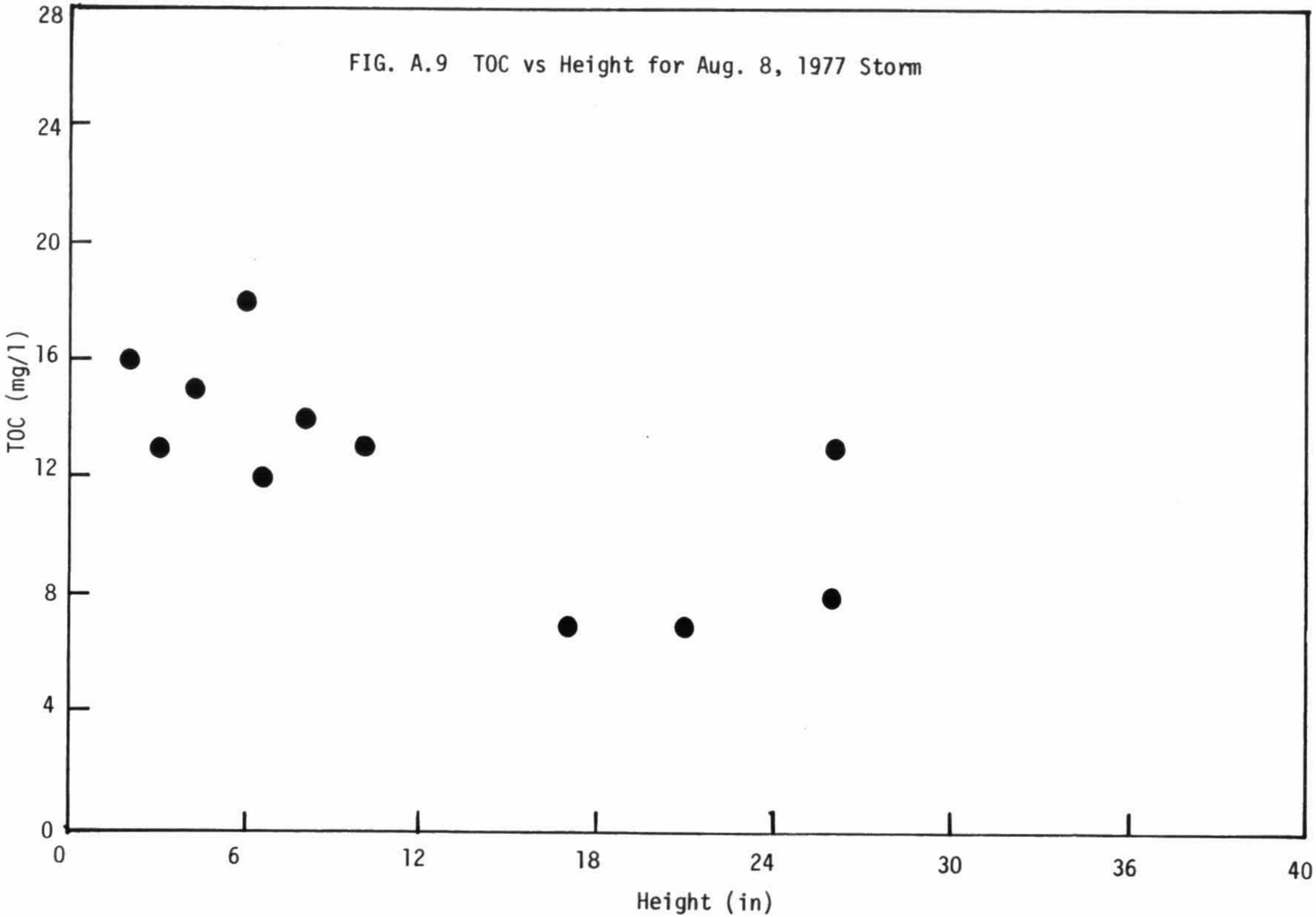


FIG. A.9 TOC vs Height for Aug. 8, 1977 Storm

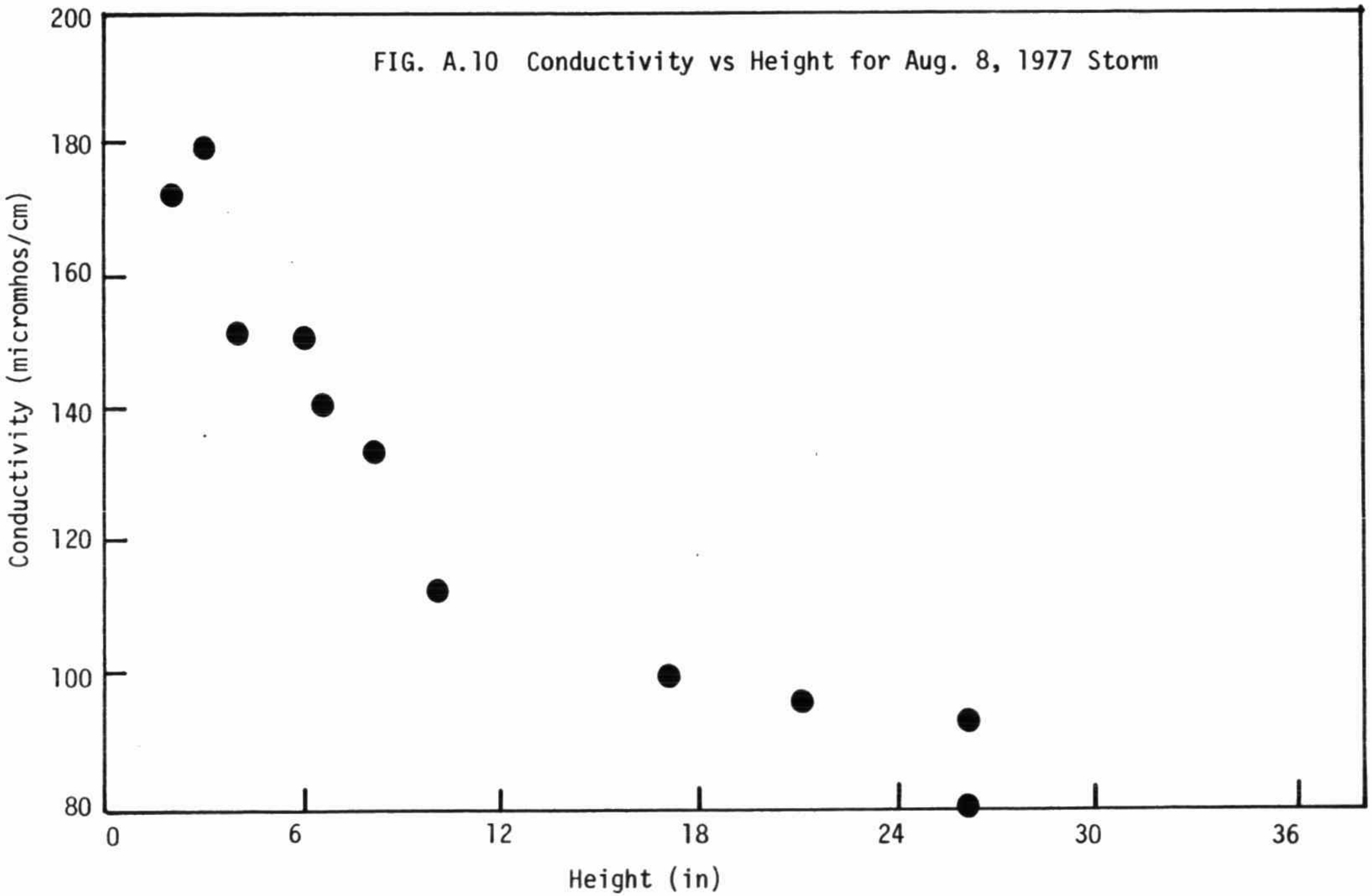


FIG. A.10 Conductivity vs Height for Aug. 8, 1977 Storm

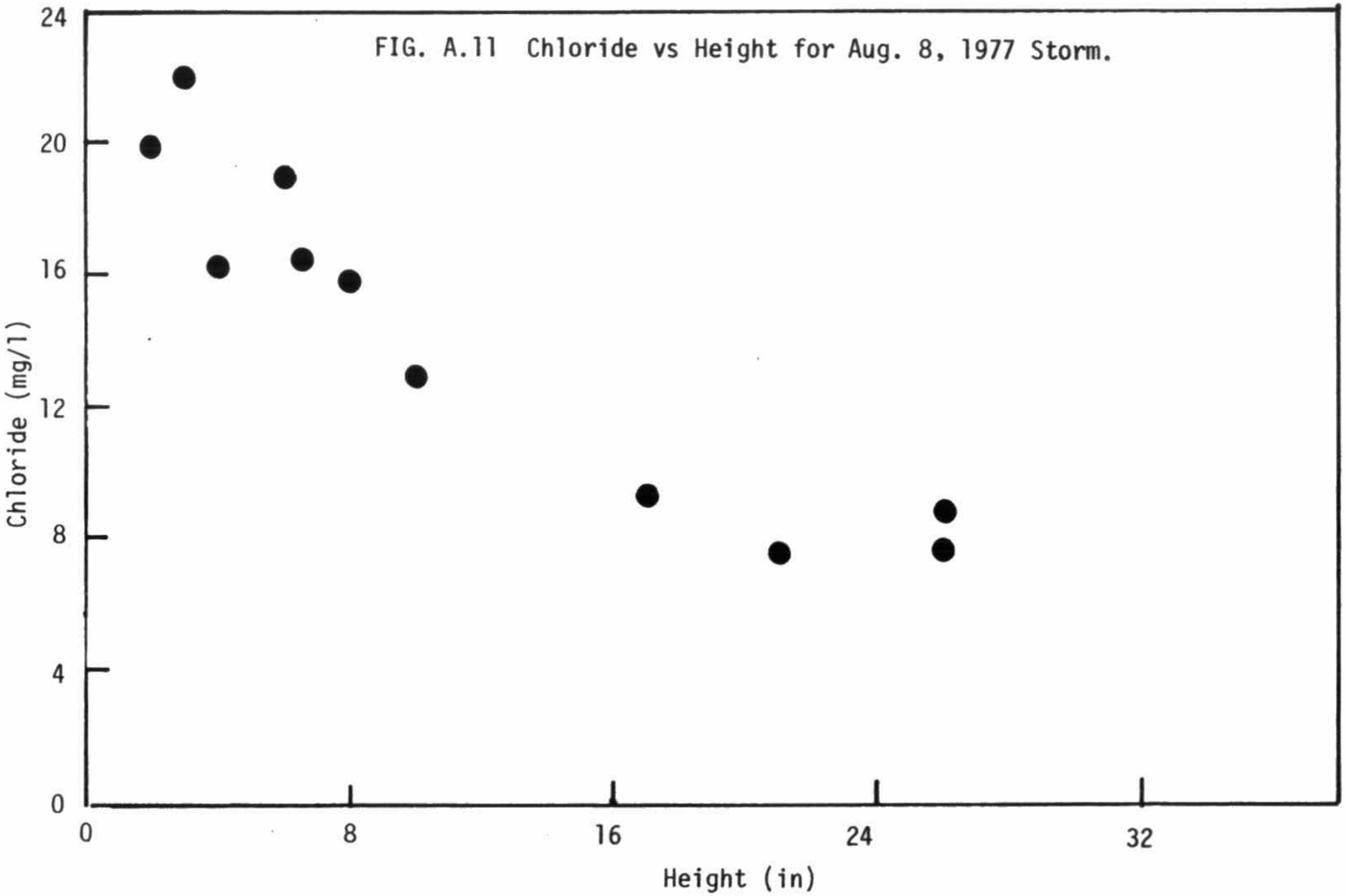


FIG. A.11 Chloride vs Height for Aug. 8, 1977 Storm.

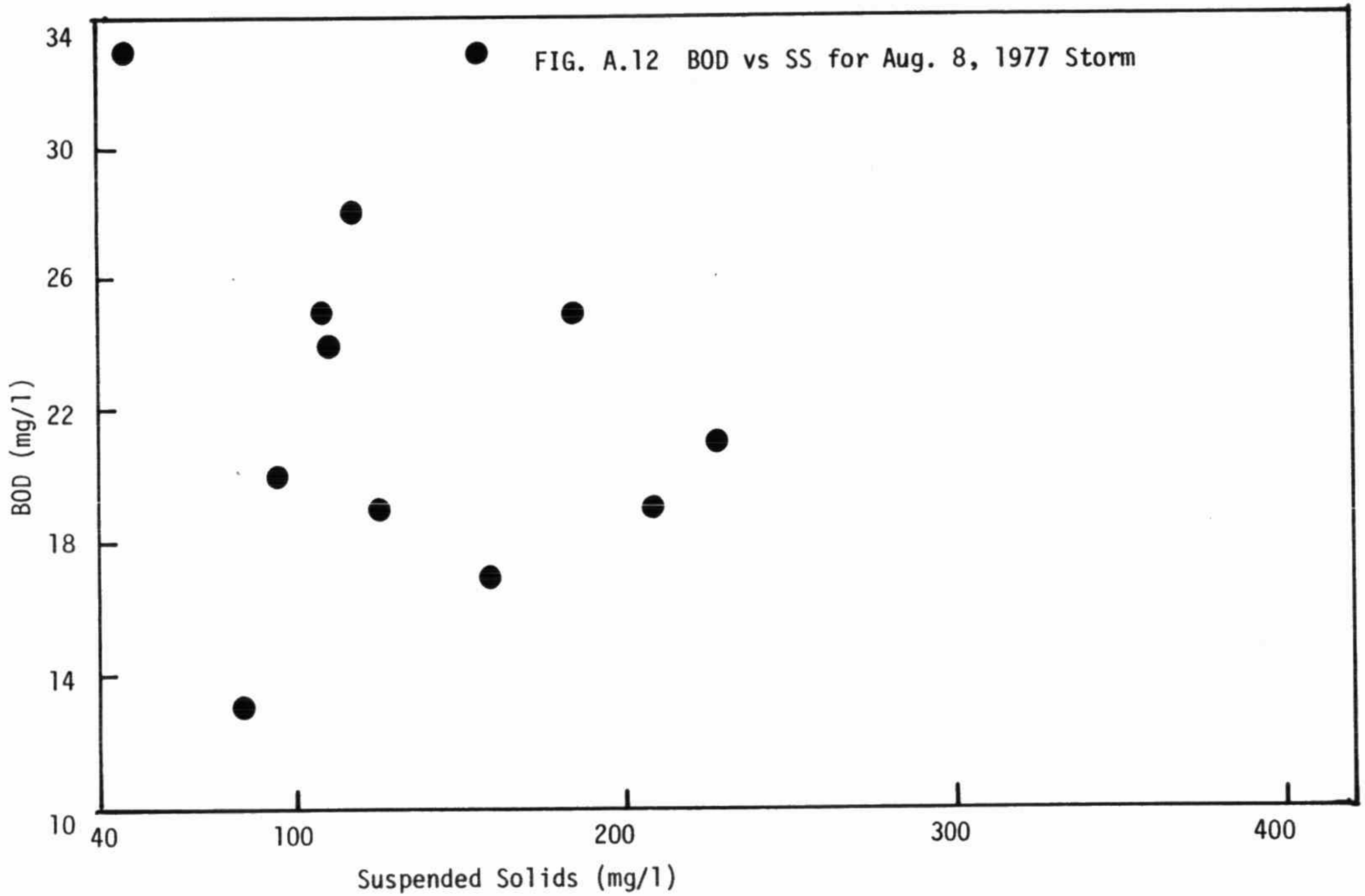


FIG. A.12 BOD vs SS for Aug. 8, 1977 Storm

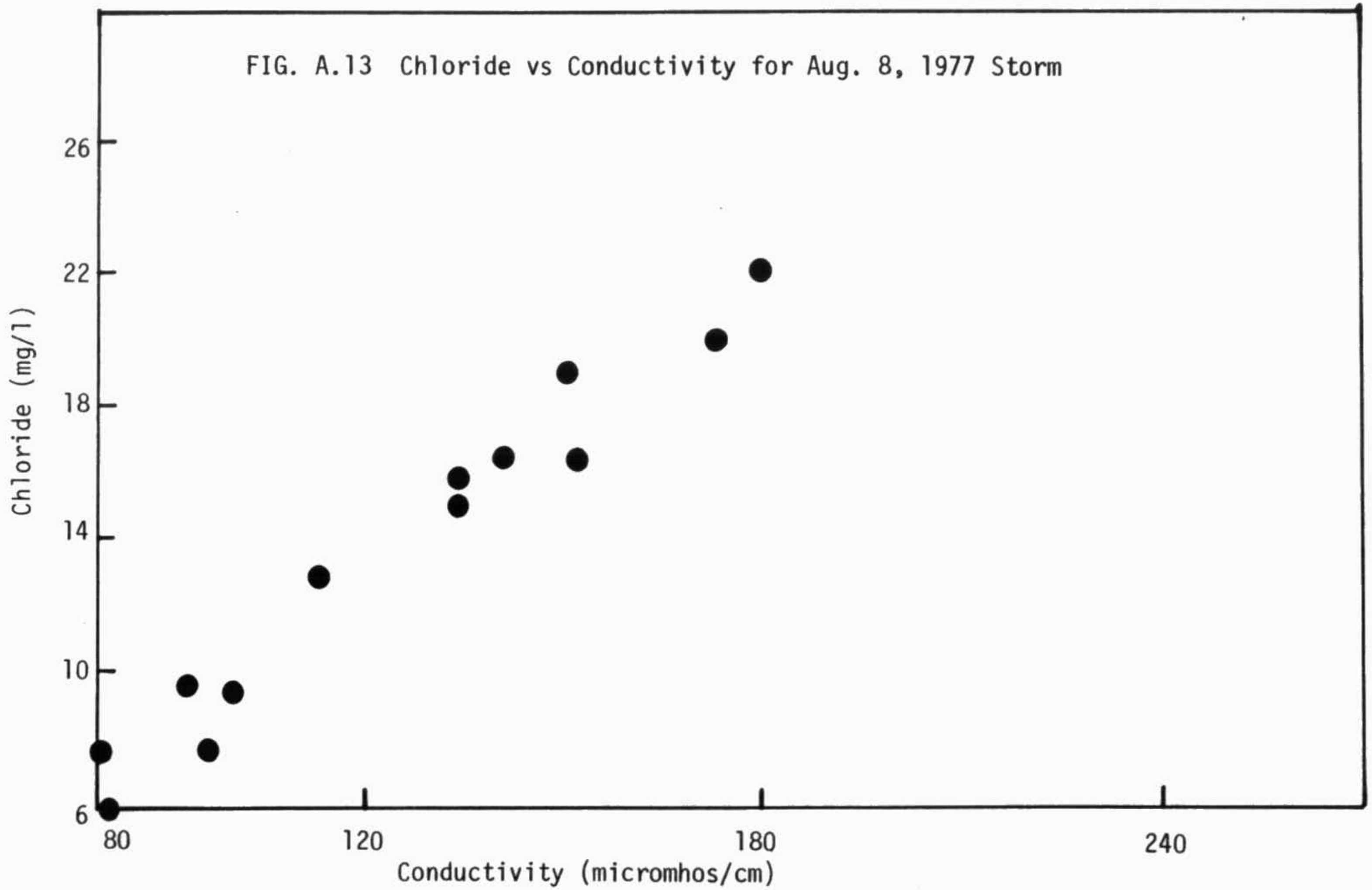


FIG. A.13 Chloride vs Conductivity for Aug. 8, 1977 Storm

APPENDIX A.2

METHODS OF CALCULATING LOADINGS TO WATER BODIES

APPENDIX A.2 METHODS OF CALCULATING LOADINGS TO WATER BODIES

In general, investigators have calculated the annual loadings (L) to a water body from a point source or stream using one of four computing formulae:

$$L = \overline{C} \cdot \overline{Q} \cdot 365 \tag{1}$$

$$L = 10^{\overline{LOGC}} \cdot Q \cdot 365 \tag{1.1}$$

$$L = \sum_{i=1}^{N} C_i \cdot Q_i \cdot \Delta t_i \tag{2}$$

$$L = 365 \sum_{j=1}^{m} P_j \cdot \overline{C}_j \cdot \overline{Q}_j \tag{3}$$

$$L = \sum_{i=1}^{365} C_i \cdot Q_i \tag{4}$$

In equations (2) and (4) C_i is the concentration (mg/m^3) measured at a hydraulic rate of flow Q_i (m^3/day) on day i, Δt_i is the length of time period between flow measurements and n is the number of measurements made during a year. $\overline{C}$ is the average annual concentration measured, and $\overline{Q}$ is the average annual flow expressed on a daily basis. In equation (3), m is the number of intervals into which all daily flows are divided, P_j is the probability of a particular flow occuring in an interval and $\overline{C}_j$ and $\overline{Q}_j$ are the average values of concentration and flow observed in that interval.

Many investigators have used equation (1) to calculate annual fluxes. But, as discussed below, it produces erroneous results for chemical parameters which are flow sensitive (e.g., total phosphorus in a disturbed watershed). Equation (4) provides the most accurate results but requires daily flow-concentration measurements - a frequency which is generally not available. Hence resort may be made to equation (3).

Bernhardt et al. (1969) found that the standard error of estimate of export from a watershed did not decrease if the sampling frequency was increased from once every two weeks to three samples weekly, using equation (2) to calculate export. Hence, they suggest that much of the scatter of data in small tributaries is due to random events (e.g., a cow grazing).

But they also suggest that the scatter may be due to peaks of rising nutrient concentrations occurring during periods of rising stage. For soluble fractions, they suggest that these peaks are due to flushing of marshes, and ditches. Jaworski et al. (1969) suggest that peaks of particulate matter may be due to purging of a water bed and thus results from sedimentation during periods of falling stage and low flow.

These observations together with previous studies on Lake Canadarago led Fuhs (1972) to use various relationships between concentration and flow. If concentration increases for increasing flow and both are normally distributed, the model tested was,

$$C = a + b\,Q \qquad (5.1)$$

$$L = a_1\,Q + b_1 Q^2 \qquad (5.2)$$

where a, b, a_1, and b_1 are regression coefficients. If concentration and flow are log normally distributed, the basic relationship is:

$$C = AQ^B \qquad (6.1)$$

$$L = AQ^{B+1} \qquad (6.2)$$

where A and B are regression coefficients. If concentration decreases with flow, either:

$$C = \frac{a_2}{Q} + b_2 \qquad (7.1)$$

$$L = a_2 + b_2 Q \qquad (7.2)$$

or

$$C = \frac{a_3}{1 + b_3 Q} \qquad (8.1)$$

$$L = \frac{a_3}{1 + b_3 Q} \qquad (8.2)$$

may form the basic relationship. The former (7.1, 7.2) was developed primarily for the case of dilution of constant waste flow, the latter was used by Fuhs in several studies since it tends to reflect changes in concentration of soluble material derived from bedrock.

20 - 26 measurements taken in a quasisynoptic fashion at equal intervals throughout one year provide the basis for the summary of Fuhs' findings in Table A.2.1. To calculate export, equations (1) and (3) were compared. In general, Fuhs found that for flow sensitive parameters, equation (3) gave significantly different values for export than those calculated using a modification of equation (1). He concludes that a positive correlation between C and Q gives a higher export value than that calculated using log mean concentrations times average flow and that a negative correlation gives a lower value. Many chemical parameters are log normally distributed; Lane and Lei's (1950) studies provided a basis for Fuhs to conclude that daily flows are log normally distributed. The effects of a distribution upon model selection are considered below.

The U.S. Corp. of Engineers (1975) found increased concentrations of total phosphorus, suspended solids, organic nitrogen and COD during storm runoff while nitrate and chloride showed no consistent trend in 8 river basins of western Ohio draining into Lake Erie; soluble P and dissolved solids decreased with increasing flow for one station indicating the influences of a point source. A strong correlation between total phosphorus and suspended solids indicate the effects of erosion at high flows on total phosphorus transport. For two basins, there was a decrease in the absolute concentration in flow sensitive parameters; in fact, total phosphorus, ammonia and nitrate generally decreased in magnitude with increasing flow for one basin (Cuyahoga). To calculate export estimates from a drainage basin, a linear model of concentration regressed upon flow rate at time of sampling is made. For example, $C = 0.1822 + 0.0000295Q$ was obtained for the Maumee total phosphorus (mg/l,Q = cfs). Then the flux is calculated according to equation (3). This approach allows calculation of the standard error of the average daily export rate.

For some cases, daily flow rates have not been measured; rather flow measurements made on the day of water quality sampling (e.g., once a week or more infrequent) are available. Application of a rainfall-runoff simulation model can provide first-order estimates of daily flow.

TABLE A 2.1

RELATIONSHIPS OBSERVED BY FUHS (1969) BETWEEN C AND Q

PARAMETER	CORRELATION C to Q	MODEL	DISTRIBUTION	REMARKS
Total CO_2	strong, negative	8.1, 8.2	*	*
Organic C	none	---	---	---
Organic particulate C	none	---	---	---
Humic Matter	strong, positive	6.1, 6.2	*	---
Soluble Reactive P	some tributaries were negative	*	*	Very low C, causing measurement errors
Total Dissolved P	negative	*	mostly Lognormal	*
Particulate P	positive	*	generally Lognormal a few normal	*
Nitrate	generally none	---	Lognormal	---
Nitrite	*	*	*	*
Ammonia	essentially none	*	Lognormal	*
Soluble Organic N	poor	---	Lognormal, substantial deviations	poor coorelation is expected for parameters influenced by biological production
Particulate N	none	---	Lognormal	---
Total N	*	---	Lognormal	Dist$\underline{n}$ found despite randomness of most components
Major Ions (Na^+ K^+, Mg^{++} Ca^{++}, Cl^-, SO $SO_4^=$, $HCO_3^=$)	negative	8.1, 8.2	Lognormal generally	*
Iron	none	*	*	*
Manganese	*	*	*	*

* No statements made concerning this category.

If backwater influences the stage, flow and flux estimates need to be examined carefully. For example, Quinn (1976) constructed a mathematical hydraulic model to estimate flows of the upper and lower ends of the Detroit River from Lake St. Clair to Lake Erie. Model application indicates that daily flow intervals suffice making annual chloride loading estimates to Lake Erie. In fact, use of hourly, daily or monthly flow intervals yield similar results for making annual estimates, but much short-term detail is lost in monthly flow calculations. For short-term detail, daily flows are adequate for most stable flow conditions, but hourly flow estimates are needed for Lake Erie wind-tide and seiche conditions. Also short-term flow estimates are necessary for comparing peak loadings between the upper and lower river. These calculations indicate that monthly sampling and flow estimates may suffice for making annual chloride loading estimates for any river similar to the Detroit River, a conclusion reached by Salbach and Casey (1974) for the Niagara River but without the benefit of an analysis like Quinn's.

The efforts of these investigators suggest that the most accurate method for calculating fluxes is use of equation (4), the daily flow record and C-Q relationship if one exists. Since many workers have found that both total phosphorus and flow are log normally distributed, then the appropriate model consists of a regression of log C upon log Q, rather than a linear model of C regressed upon Q. While their data were not evaluated by this writer, the linear model used by the Army Corp. (1975) is inappropriate if these quantities are log normally distributed.

To determine whether such a C-Q relationship exists, one should have some evidence for justifying such a relationship. Generally, this writer concludes that an increasing concentration will occur with increasing flow in disturbed watersheds for chemical parameters which are subject to erosion (e.g., suspended solids, the particulate fraction of total phosphorus). Such a relationship was observed for BOD,SS and TP in the James St. overflow (Appendix A.1). A stronger C-Q relationship is expected in more strongly disturbed watersheds (e.g., forested and pasture vs. agricultural vs. urban areas).

Dillon (personal communication) has concluded that for most non-disturbed forested areas, no C-Q relationship exists, implying that erosive processes are random events rather than rainfall-related events. The work of investigators as Fuhs (1972), the U.S. Army Corp. (197) etc. is for very disturbed areas. Where chemical leaching or dilution of a point source input by storm water occurs, an inverse relationship between C and Q is often found. Such a relationship was observed on the James St. sewer for conductivity and chlorides.

To examine the effect of C-Q relationships upon loading calculations, a synthetic flow pattern was used with varying C-Q relationships. The flow pattern used was the daily flows of the Grand River at Brantford in 1974, which varied between 15.3 and 1030 m^3s^{-1}. Table A.2.2 shows the loads caluclated for various assumption of C-Q relationships and different combinations of inputs from erosion controlled processes and of inputs from dilution -controlled processes. Daily values of C are estimated as a function of Q using $C = C_oQ^S$ where S various from 0 to 0.5 and reflects an increasingly strong C-Q relationship. The constant C_o in determined such that the concentration of an erodable material is always 40 ug/l at a flow rate of 14.2 m^3s^{-1}(500 cfs), for each value of S; 14.2 m^3s^{-1} is the lower end of the synthetic flow pattern. Such C-Q relationship represent hypothesized relationships for an erosion controlled parameter. L1 is the load calculated for each C-Q relationship using equation 4, which L2 is the load calculated using equation 1. Next a daily concentration profile is estimated for a constant point source input for the synthetic flow pattern. This represents dilution of a constant source input and is calculated by dividing the input rate (e.g. Kgs^{-1}) by the flow rate (m^3s^{-1}). The input rate is taken as a fraction, "FRAC", of the load calculated in L1. L3 is the load calculated for this dilution-concentration pattern using equation 4 while L4 is the load calculated using equation 1. Thus for example, for FRAC = 1, the values of L1 and L3 are the same for a given flow exponent S.

To simulate parameters which are affected both by dilution of point source inputs and erosive processes, the concentration for the erosion controlled pattern is added to the concentration of the dilution controlled pattern.

Three different combinations are shown - one in which the point source diluted input is 0% of the annual average erosion controlled loading (FRAC = 0, Table A.2.2a), one in which FRAC = 1.0 (Table A.2.2b) and one in which FRAC = 1.67. For this concentration profile, equation 4 (L5) and equation 1 (L6) are used to calculate the loading.

For the erodable material equation 1 always underestimates the loading, compared to equation 4 (Compare L1 to L2 in Table A.2.2). This error increases from 0 to 25% on the strength of the C-Q relationship increases. For the dilution of a point source, equation 1 always overestimates the loading (compare L3 to L4 in Table A.2.2) by approximately 60%. For a material affected both by erosion and dilution, equation 1 (L6) always overestimates the actual loading (L5, equation 4). For the particular case (FRAC = 1) where the average annual loading from an erodable source is equal to that of an annual loading from a point source the overestimate decreases (from 28% to 16%) as the strength of the C-Q relationship for the erodable material increases. Such a soluble phosphorus and particulate phosphorus. For materials which are not flow sensitive (S = 0), equation 1 and equation 4 give the same values for loading.

1. For disturbed watersheds, event oriented sampling is necessary for flow-affected chemical parameters. Further, sampling over two different hydrographs can often give two different chemographs. This allows determination of whether a shift in the C-Q relationship occurs. With this data, we propose the following:

   (i) if no significant shift occurs, then sampling one chemograph together with the daily flow record may be a sufficiently accurate data base for estimating export.

   (ii) if a shift occurs, then several hydrographs need to be sampled to determine whether seasonal or other factors are involved, and

   (iii) due to the large amount of runoff during the spring, particular efforts need to be made to adequately sample spring runoff events.

TABLE A.2.2 Calculated loading (kg/day) passing a given point for a given synthetic flow pattern and for a given concentration (C) flow (Q) relationship, $C = C_0Q^S$

A.2.2(a) Loading Calculations for an erodable material (FRAC = 0)

.1757

175.7

S	L1	L2
0	[illegible]	[illegible]
0.05	[illegible]	[illegible]
0.10	[illegible]	[illegible]
0.15	[illegible]	[illegible]
0.20	[illegible]	[illegible]
0.25	[illegible]	[illegible]
0.30	[illegible]	[illegible]
0.35	[illegible]	[illegible]
0.40	[illegible]	[illegible]
0.45	[illegible]	[illegible]
0.50	[illegible]	[illegible]

A.2.2(b) Loading calculations for the erodable material and for the dilution of a point source whose magnitude is equal to that of the annual average of the erodable material (FRAC = 1.0)

S	L1	L2	L3	L4	L5	L6
0.00	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
0.05	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
0.00	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
0.15	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
0.20	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
0.25	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
0.30	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
0.35	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
0.40	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
0.45	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
0.50	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

A.2.2(c) Loading Calculations for the erodable material and for the dilution of a point source whose magnitude is 1.67 times that of the annual average of the erodable material (FRAC = 1.67).

S	L1	L2	L3	L4	L5	L6
0.00	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
0.05	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
0.10	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
0.15	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
0.20	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
0.25	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
0.30	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
0.35	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
0.40	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
0.45	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
0.50	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

For L1, L2, etc., see text.

2. Analogous to the Canada Water Survey, a Chemical Water Survey may be necessary on a systematic comprehensive basis as planning needs of many different groups become larger and more overlapping. Such a chemical or biological survey will become cost effective when the total cost to many firms and agencies becomes more than the cost of a survey conducted by one agency.

SUMMARY

For calculation of fluxes, this writer assesses that equation 4 is the most appropriate. Equation 3 is equally valid by a somewhat less precise method. Equation 1 gives erroneous results for all chemical substances which are flow sensitive . Equation 2 is applicable to undisturbed watersheds (i.e. where C is not a function of Q) except that Q_i, the flow on the day of sampling - will not normally be an adequate representation of the variations in flow during the period between sampling. Accordingly equation 2 is rejected unless Q_i is substituted for by actual flow between sampling intervals. If the between interval flow is substituted, then equations 1 and 2 should approximate the same value except that the product of a series of sums (equation 1) rarely equals the sum of a series of products (equation 2). With this qualification, then equation 1 or 2 would give roughly equal, correct estimates of loadings for parameters which are not flow dependent as would use of equation 3 or 4.

For a chemical parameter (C) and flow parameter Q which are each log normally distributed, the appropriate model to ascertain whether a C-Q relationship exists is $\text{Log } C = M \text{ Log } Q + \text{Log } a$, where m is the intercept. The significance of m can be tested using normal statistics (e.g. using the null hypothesis that $m = 0$).

The appropiate method for calculating annual export is $\text{Export} = \sum_{t=1}^{365} C\ (Q_t).\ Q_t/\text{D.A.}$ where Q_t is the daily flow record, $C(Q_t)$ is the area of the drainage area. Estimates of export for more than one year should be formulated as a function of the different amounts of annual runoff and any changes in he C-Q relationship which one observes from year to year.

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SOURCES OF INFORMATION

Input Point		Data Source
Hamilton WWTP		Hamilton WWTP Annual Reports
Burlington WWTP		Burlington WWTP Monitoring Program (MOE, Central Region)
Industrial	1.	Stelco and Dofasco Corporate Monitoring Program -each parameter having 3 samples per year -each parameter from 1973-77 which has no value given for number of samples.
	2.	MOE Regional Office Surveillance Program -each parameter having 3 samples per year. -all data for 1971 and 1972 except for the following which are from the Industrial Corporate Program.
	(i)	Ammonia - Dofasco - all data - Stelco - WSOC, BSPH #1, BSPH #2
	(ii)	COD - Stelco - WSOC, BSPH #1, BSPH #2
	(iii)	SS - Dofasco - all data
	(iv)	Iron - Stelco and Dofasco - all data
	(v)	Cr - Dofasco - all data
	(vi)	Ether Solubles - Dofasco - all data
	(vii)	Cyanide - Dofasco - all data Stelco - North Trunk, W.S.O.C., BSPH #1, BSPH#2.
	(viii)	Phenol - Dofasco - all data; Stelco - W.S.O.C., BSPH #1, BSPH #2
Streams	1.	1971 - 1976 - data from Sanitary Survey of HRCA streams except for TKN, COD, BOD5, Cond., TOC, Filt TOC, listed under Red Hill, 1976 which is Poulton's Exp. '77 data for Red Hill Cr. 1977.
	2.	1977 - McMaster Exp. '77 group.
Stormwater Overflows	1.	Data listed under 1976 heading is Poulton's Exp. '77 data for 1977.
	2.	2977 - McMaster Exp. '77 group
Cootes Paradise		MOE Regional Office Report on Cootes Paradise.

TABLE A.2.2 Calculated loading (kg/day) passing a given point for a given synthetic flow pattern and for a given concentration (C) flow (Q) relationship, $C = C_o Q^s$

A.2.2(a) Loading Calculations for an erodable material (FRAC = 0)

S	L1	L2
0	.1757E+03	.1757E+03
0.05	.1900E+03	.1851E+03
0.10	.2056E+03	.1952E+03
0.15	.2223E+03	.2061E+03
0.20	.2419E+03	.2178E+03
0.25	.2623E+03	.2305E+03
0.30	.2860E+03	.2442E+03
0.35	.3116E+03	.2591E+03
0.40	.3393E+03	.2753E+03
0.45	.3713E+03	.2928E+03
0.50	.4060E+03	.3119E+03

A.2.2(b) Loading calculations for the erodable material and for the dilution of a point source whose magnitude is equal to that of the annual average of the erodable material (FRAC = 1.0)

S	L1	L2	L3	L4	L5	L6
0.00	.1757E+03	.1757E+03	.1757E+03	.2742E+03	.3515E+03	.4500E+03
0.05	.1900E+03	.1851E+03	.1900E+03	.2964E+03	.3800E+03	.4815E+03
0.00	.2056E+03	.1952E+03	.2056E+03	.3209E+03	.4113E+03	.5161E+03
0.15	.2223E+03	.2061E+03	.2223E+03	.3478E+03	.4458E+03	.5539E+03
0.20	.2419E+03	.2178E+03	.2419E+03	.3775E+03	.4838E+03	.5953E+03
0.25	.2623E+03	.2305E+03	.2623E+03	.4102E+03	.5258E+03	.6407E+03
0.30	.2860E+03	.2442E+03	.2860E+03	.4463E+03	.5721E+03	.6906E+03
0.35	.3116E+03	.2591E+03	.3116E+03	.4863E+03	.6233E+03	.7454E+03
0.40	.3393E+03	.2753E+03	.3393E+03	.5304E+03	.6799E+03	.8057E+03
0.45	.3713E+03	.2928E+03	.3713E+03	.5793E+03	.7425E+03	.8722E+03
0.50	.4060E+03	.3119E+03	.4060E+03	.6335E+03	.8120E+03	.9454E+03

A.2.2(c) Loading Calculations for the erodable material and for the dilution of a point source whose magnitude is 1.67 times that of the annual average of the erodable material (FRAC = 1.67).

S	L1	L2	L3	L4	L5	L6
0.00	.1757E+03	.1757E+03	.2929E+03	.4570E+03	.4686E+03	.6328E+03
0.05	.1900E+03	.1851E+03	.3166E+03	.4941E+03	.5066E+03	.6792E+03
0.10	.2056E+03	.1952E+03	.3427E+03	.5348E+03	.5484E+03	.7300E+03
0.15	.2223E+03	.2061E+03	.3715E+03	.5797E+03	.5944E+03	.7857E+03
0.20	.2419E+03	.2178E+03	.4032E+03	.6291E+03	.6451E+03	.8469E+03
0.25	.2623E+03	.2305E+03	.4391E+03	.6837E+03	.7010E+03	.9142E+03
0.30	.2860E+03	.2442E+03	.4767E+03	.7439E+03	.7628E+03	.9881E+03
0.35	.3116E+03	.2591E+03	.5194E+03	.8105E+03	.8310E+03	.1070E+04
0.40	.3393E+03	.2753E+03	.5666E+03	.8841E+03	.9065E+03	.1159E+04
0.45	.3713E+03	.2928E+03	.6138E+03	.9656E+03	.9901E+03	.1258E+04
0.50	.4060E+03	.3119E+03	.6766E+03	.1056E+04	.1083E+04	.1363E+04

For L1, L2, etc., see text.

TABLE A.2.2 Calculated loading (kg/day) passing a given point for a given synthetic flow pattern and for a given concentration (C) flow (Q) relationship, $C = C_0Q^s$

A.2.2(a) Loading Calculations for an erodable material (FRAC = 0)

S	L1	L2
0	175.7	175.7
0.05	190.0	185.1
0.10	205.6	195.2
0.15	222.9	206.1
0.20	241.9	217.8
0.25	262.9	230.5
0.30	286.0	244.2
0.35	311.6	259.1
0.40	339.9	275.3
0.45	371.3	292.8
0.50	406.0	311.9

A.2.2(b) Loading calculations for the erodable material and for the dilution of a point source whose magnitude is equal to that of the annual average of the erodable material (FRAC = 1.0)

S	L1	L2	L3	L4	L5	L6
0.00	175.7	175.7	175.7	274.2	351.5	450.0
0.05	190.0	185.1	190.0	296.4	380.0	481.5
0.00	205.6	195.2	205.6	320.9	411.3	516.1
0.15	222.9	206.1	222.9	347.8	445.8	553.9
0.20	241.9	217.8	241.9	377.5	483.8	595.3
0.25	262.9	230.5	262.9	410.2	525.8	640.7
0.30	286.0	244.2	286.0	446.3	572.1	690.6
0.35	311.6	259.1	311.6	486.3	623.3	745.4
0.40	339.9	275.3	339.9	530.4	679.9	805.7
0.45	371.3	292.8	371.3	579.3	742.5	872.2
0.50	406.0	311.9	406.0	633.5	812.0	945.4

A.2.2(c) Loading Calculations for the erodable material and for the dilution of a point source whose magnitude is 1.67 times that of the annual average of the erodable material (FRAC = 1.67).

S	L1	L2	L3	L4	L5	L6
0.00	175.7	175.7	292.9	457.0	468.6	632.8
0.05	190.0	185.1	316.6	494.1	506.6	679.2
0.10	205.6	195.2	342.7	534.8	548.4	730.0
0.15	222.9	206.1	371.5	579.7	594.4	785.7
0.20	241.9	217.8	403.2	629.1	645.1	846.9
0.25	262.9	230.5	438.1	683.7	701.0	914.2
0.30	286.0	244.2	476.7	743.9	762.8	988.1
0.35	311.6	259.1	519.4	810.5	831.0	107.0
0.40	339.9	275.3	566.6	884.1	906.5	115.9
0.45	371.3	292.8	618.8	965.6	990.1	125.8
0.50	406.0	311.9	676.6	105.6	108.3	136.8

For L1, L2, etc., See text.

APPENDIX A.3
CONCENTRATIONS IN OUTFALLS, STREAMS AND STORM SEWERS FLOWING TO HAMILTON HARBOUR FOR THE PERIOD 1971 to 1977

TOTAL PHOSPHORUS

SOURCE	1971 MEAN	1972 MEAN	1973 MEAN	1973 STD	1973 NO	1974 MEAN	1974 STD	1974 NO	1975 MEAN	1975 STD	1975 NO	1976 MEAN	1976 STD	1976 NO	1977 MEAN	1977 STD	1977 NO
HAMILTON WWTP									1.900			1.500	.360	12	1.290	.450	12
BURLINGTON WWTP	4.000	3.200	2.200			2.900			1.900			1.000			.800		
STELCO HOT STRIP FINISHING	.080	.190				.120		1	.040		1				.200		1
STELCO EAST SIDE LAGOON	.200	.380	.150		1	.120		1	.040		1	.460		1	.200	.090	3
STELCO OIL RECOVERY PLANT												.300		1	.190	.080	3
STELCO 148 IN PLATE MILL	.100	.100	.200		1	.200		1									
STELCO NO 3 O.H. COOLING	.100	.100	.100		1	.200		1				.060		1	.130	.080	3
STELCO NORTH TRUNK	.100	.140	.200		1	.120		1	.080		1	.100		1	.200	.200	3
STELCO WEST SIDE OPEN CUT	.100	.200	.100		1	.160		1	.080		1	.100		1	.090	.050	3
STELCO NO 1 BSPH						.260		1				.060		1	.120	.030	2
STELCO NO 2 BSPH	.060					.190		1	.060		1	.200		1	.100	.010	3
STELCO COLD MILL TO CITY STORM																	
STELCO NO 2 ROD MILL																	
STELCO ONTARIO WORKS 28 IN MIL																	
DOFASCO LAGOON OVERFLOW		.180	.130		2				.080		1	.120		1	.170	.100	3
DOFASCO COKE PLANT	.050	.020	.160		2				.120		1	.080		1	.130	.040	3
DOFASCO OTTAWA STREET	.400	.020	.250		2				.120		1	.080		1	.330	.250	3
DOFASCO BOILER HOUSE	.700	?.100	.160		2				.120		1	.160		1	.190	.090	3
DOFASCO BAY WATER INTAKE	.050	.140	.150		2				.080		1	.080		1	.160	.110	3
STREAMS RED HILL CREEK			1.380	1.520	9	.350		17	.380	.160	9	.363	.093	9	.800	.500	9
STREAMS GRINDSTONE			.162			.170			.180						.352	.176	27
STREAMS BURLINGTON OPEN CHANNL															.031	.014	15
STREAMS FALCON CREEK															.086		
STREAMS ALDERSHOT DRAIN															.086	.082	15
STM OVERFLW 1 QUEEN																	
STM OVERFLW2 CAROLINE																	
STM OVERFLW 4 MARSHALL																	
STM OVERFLW 5 JAMES												.165		4			
STM OVERFLW 6,7,8 CATHER-WELLN												.035		11			
STM OVERFLW9 WENTWORTH												.107		3			
STM OVERFLW 11 BIRCH												1.150		4			
STM OVERFLW 12 GAGE																	
STM OVERFLW 13 OTTAWA												.173		4	1.370	2.390	11
STM OVERFLW 14 KENILWORTH												.128		4	1.330	1.150	18
STM OVERFLW 15 STRATHEARNE												.780		4	.325	.390	8
STM OVERFLW 16 PARKDALE												4.100		3	2.270	1.890	18
COOTES PARADISE									.400								

SOLUBLE PHOSPHORUS

SOURCE	1971 MEAN	1972 MEAN	1973 MEAN	1973 STD	1973 NO	1974 MEAN	1974 STD	1974 NO	1975 MEAN	1975 STD	1975 NO	1976 MEAN	1976 STD	1976 NO	1977 MEAN	1977 STD	1977 NO
HAMILTON WWTP												.390	.170	12	.760	.330	12
BURLINGTON WWTP																	
STELCO HOT STRIP FINISHING		.100	.400		1				.020		**				<.020		1
STELCO EAST SIDE LAGOON		.100	.100		1				.020		**	.440			<.020		1
STELCO OIL RECOVERY PLANT												.280			<.020		1
STELCO 148 IN PLATE MILL		<.100	<.100		1												
STELCO NO 3 O.H. COOLING		≤.100	.100		1				<.020		1	.040			<.020		1
STELCO NORTH TRUNK		<.100	<.100		1				<.020		1	.080			<.020		1
STELCO WEST SIDE OPEN CUT		.100	<.100		1				<.020		1	.080			<.020		1
STELCO NO 1 BSPH												.040			<.020		1
STELCO NO 2 BSPH									<.020		1	.180			<.020		1
STELCO COLD MILL TO CITY STORM		<.100	.100		1												
STELCO NO 2 ROD MILL																	
STELCO ONTARIO WORKS 28 IN MIL																	
DOFASCO LAGOON OVERFLOW		<.100	.100		2				.020		1	.110		1	<.020		3
DOFASCO COKE PLANT		<.100	.100		2				.020		1	.060		1	<.020		3
DOFASCO OTTAWA STREET		<.100	.100		2				.020		1	.060		1	<.020		3
DOFASCO BOILER HOUSE		<.050	.100		2				.020		1	.150		1	<.020		3
DOFASCO BAY WATER INTAKE		<.100	.150		2				.080		1	.060		1	<.020		3
STREAMS RED HILL CREEK			1.250	.260	9	.320	.190	17	.330	.170	9	.315	.107	9	.160	.030	3
STREAMS GRINDSTONE			.042			.050			.060						.222	.098	17
STREAMS BURLINGTON OPEN CHANNEL															.013	.010	12
STREAMS FALCON CREEK																	
STREAMS ALDERSHOT DRAIN															.030	.062	12
STM OVERFLW 1 QUEEN																	
STM OVERFLW2 CAROLINE																	
STM OVERFLW 4 MARSHALL																	
STM OVERFLW 5 JAMES												.062		4			
STM OVERFLW 6,7,8 CATHER-WELLN												.152		11			
STM OVERFLW9 WENTWORTH												.029		3			
STM OVERFLW 11 BIRCH												.890		4			
STM OVERFLW 12 GAGE																	
STM OVERFLW 13 OTTAWA												.012		4	.440	.430	8
STM OVERFLW 14 KENILWORTH												.039		4	.760	.660	11
STM OVERFLW 15 STRATHEARNE												.240		4	.110	.220	8
STM OVERFLW 16 PARKDALE												1.800		4	1.670	.880	11
COOTES PARADISE									.057								

AMMONIA

SOURCE	1971 MEAN	1972 MEAN	1973 MEAN	1973 STD	1973 NO	1974 MEAN	1974 STD	1974 NO	1975 MEAN	1975 STD	1975 NO	1976 MEAN	1976 STD	1976 NO	1977 MEAN	1977 STD	1977 NO
HAMILTON WWTP												39.400	10.600	12	41.800	8.300	9
BURLINGTON WWTP	2.600	1.200	2.000			1.300						9.200			8.000		
STELCO HOT STRIP FINISHING	.200	1.700	< .100		2	.200		1							.100		1
STELCO EAST SIDE LAGOON	.200	4.400	1.900		2	.300		1	.400		1	1.700		1	.300	.200	3
STELCO OIL RECOVERY PLANT												1.300		1	.300	.200	3
STELCO 148 IN PLATE MILL	.200	4.700	2.600		2	.200		1	.800		1						
STELCO NO 3 O.H. COOLING	.650	4.600	.100		2	.300		1	.100		1	4.100		1	.400	.300	3
STELCO NORTH TRUNK	7.200	9.800	1.900		2	1.100		1	.100		1	3.800	3.100	14	14.900	27.900	12
STELCO WEST SIDE OPEN CUT	42.300	55.860	16.900			5.100			6.100			5.100	1.900	14	5.100	2.070	12
STELCO NO 1 BSPH	3.025	4.399	2.c60			3.330			5.400			2.400	2.300	5	3.680	2.300	12
STELCO NO 2 BSPH	5.930	6.840	11.100			2.320			3.400			3.800	1.000	12	2.750	2.430	12
STELCO COLD MILL TO CITY STORM	.840	7.900	1.000		2	.300		1									
STELCO NO 2 ROD MILL																	
STELCO ONTARIO WORKS 20 IN MIL																	
DOFASCO LAGOON OVERFLOW	6.760	4.950	6.570			5.100			5.040			6.610	2.670	12	5.810	1.920	12
DOFASCO COKE PLANT	13.860	6.760	16.030			35.600			18.600			23.400	16.400	12	18.390	8.170	12
DOFASCO OTTAWA STREET	2.660	2.210	3.500			1.800			3.800			5.260	1.380	12	5.230	2.360	12
DOFASCO BOILER HOUSE	7.000		5.190			2.630			4.400			4.550	1.600	11	5.660	1.540	11
DOFASCO BAY WATER INTAKE	3.500	2.990	5.340			2.900			3.400			3.700	1.260	11	4.510	1.080	12
STREAMS RED HILL CREEK			12.600	11.200	9	4.130		17	3.960	1.550	9	2.680	1.600	9	.930	.080	3
STREAMS GRINDSTONE			.210			.170			.180						.029	.019	18
STREAMS BURLINGTON OPEN CHANNL															.012	.009	12
STREAMS FALCON CREEK																	
STREAMS ALDERSHOT DRAIN															.054	.009	12
STM OVERFLW 1 QUEEN																	
STM OVERFLW2 CAROLINE																	
STM OVERFLW 4 MARSHALL																	
STM OVERFLW 5 JAMES												1.470		4			
STM OVERFLW 6,7,8 CATHER-WELLN												1.720		11			
STM OVERFLWS WENTWORTH												1.230		3			
STM OVERFLW 11 BIRCH												4.940		4			
STM OVERFLW 12 GAGE																	
STM OVERFLW 13 OTTAWA												1.110		4	.940	1.070	8
STM OVERFLW 14 KENILWORTH												2.220		4	5.880	4.250	11
STM OVERFLW 15 STRATHEARNE												5.700		4	3.130	2.100	8
STM OVERFLW 16 PARKDALE												9.800		3	10.300	4.000	11
COOTES PARADISE									.340								

TOTAL KJELDAHL NITROGEN

SOURCE	1971	1972	1973			1974			1975			1976			1977		
	MEAN	MEAN	MEAN	STD	NO	MEAN	STD	NO	MEAN	STD	NO	MEAN	STD	NO	MEAN	STD	NO
HAMILTON WWTP															16.700	2.400	9
BURLINGTON WWTP	4.100	4.000	3.000			3.000			4.000			2.900			9.000		
STELCO HOT STRIP FINISHING		1.420	16.100		2												
STELCO EAST SIDE LAGOON	.750	4.300	11.200		2												
STELCO OIL RECOVERY PLANT																	
STELCO 148 IN PLATE MILL	9.300	4.000	5.300		2												
STELCO NO 3 O.H. COOLING	3.100	4.200	4.500		2												
STELCO NORTH TRUNK	9.200	7.800	7.300		2												
STELCO WEST SIDE OPEN CUT	500.000	32.000	11.200		2												
STELCO NO 1 BSPH																	
STELCO NO 2 BSPH	1.500																
STELCO COLD MILL TO CITY STORM		5.500	5.700		2												
STELCO NO 2 ROD MILL																	
STELCO ONTARIO WORKS 26 IN MIL																	
DOFASCO LAGOON OVERFLOW		5.400	6.200	2.600	3												
DOFASCO COKE PLANT	26.000	27.000	15.300	16.100	3												
DOFASCO OTTAWA STREET	1.600	1.700	4.200	.200	3												
DOFASCO BOILER HOUSE	5.500	9.300	4.700	1.000	3												
DOFASCO BAY WATER INTAKE	.860	3.200	4.300	2.600	3												
STREAMS RED HILL CREEK			17.400			18.000						17.900		5	2.050	.220	3
STREAMS GRINDSTONE			1.370			1.300			1.340						.824	.180	18
STREAMS BURLINGTON OPEN CHANNL															.450	.070	12
STREAMS FALCON CREEK																	
STREAMS ALDERSHOT DRAI															.310	.062	12
STM OVERFLW 1 QUEEN																	
STM OVERFLW2 CAROLINE																	
STM OVERFLW 4 MARSHALL																	
STM OVERFLW 5 JAMES												2.580		4			
STM OVERFLW 6,7,8 CATHER-WELLN												3.110		11			
STM OVERFLW9 WENTWORTH												2.530		3			
STM OVERFLW 11 BIRCH												7.100		4			
STM OVERFLW 12 GAGE																	
STM OVERFLW 13 OTTAWA												1.950		4	3.370	2.890	8
STM OVERFLW 14 KENILWORTH												3.820		4	9.800	6.500	11
STM OVERFLW 15 STRATHEARNE												8.600		4	4.240	3.000	8
STM OVERFLW 16 PARKDALE												20.400		3	18.200	4.700	11
COOTES PARADISE									2.470								

NITRATE

SOURCE	1971 MEAN	1972 MEAN	1973 MEAN	1973 STD	1973 NO	1974 MEAN	1974 STD	1974 NO	1975 MEAN	1975 STD	1975 NO	1976 MEAN	1976 STD	1976 NO	1977 MEAN	1977 STD	1977 NO
HAMILTON WWTP												.220	.240	11	3.400	4.000	9
BURLINGTON WWTP	8.600	5.800	6.920			9.100			7.400			1.600			2.500		
STELCO HOT STRIP FINISHING		.800	.100		2												
STELCO EAST SIDE LAGOON		1.900	1.900		2												
STELCO OIL RECOVERY PLANT																	
STELCO 148 IN PLATE MILL		2.400	2.600		2												
STELCO NO 3 O.H. COOLING		1.600	.100		2												
STELCO NORTH TRUNK		1.700	1.800		2												
STELCO WEST SIDE OPEN CUT		1.500	1.800		2												
STELCO NO 1 BSPH																	
STELCO NO 2 BSPH																	
STELCO COLD MILL TO CITY STORM		1.700	1.000		2												
STELCO NO 2 ROD MILL																	
STELCO ONTARIO WORKS 28 IN MIL																	
DOFASCO LAGOON OVERFLOW		1.500	1.300	.300	3												
DOFASCO COKE PLANT		1.600	1.400	.400	3												
DOFASCO OTTAWA STREET		1.050	1.000	.600	3												
DOFASCO BOILER HOUSE		.550	1.300	.300	3												
DOFASCO BAY WATER INTAKE		1.500	1.500	.500	3												
STREAMS RED HILL CREEK			.600	.340	9	1.130		17	.920	.550	9	1.110	.650	9	1.140	.140	3
STREAMS GRINDSTONE															2.290	.680	18
STREAMS BURLINGTON OPEN CHANNL															3.710	1.400	12
STREAMS FALCON CREEK																	
STREAMS ALDERSHOT DRAIN															4.240	.450	12
STM OVERFLW 1 QUEEN																	
STM OVERFLW2 CAROLINE																	
STM OVERFLW 4 MARSHALL																	
STM OVERFLW 5 JAMES												1.940		4			
STM OVERFLW 6,7,8 CATHER-WELLN												1.200		11			
STM OVERFLW9 WENTWORTH												2.000		3			
STM OVERFLW 11 BIRCH												.166		4			
STM OVERFLW 12 GAGE																	
STM OVERFLW 13 OTTAWA												2.600		4	1.800	.520	8
STM OVERFLW 14 KENILWORTH												2.800		4	.770	.780	11
STM OVERFLW 15 STRATHEARNE												2.400		4	1.770	.670	8
STM OVERFLW 16 PARKDALE												.460		3	.572	.579	11
COOTES PARADISE									.360								

NITRITE

SOURCE	1971 MEAN	1972 MEAN	1973 MEAN	1973 STD	1973 NO	1974 MEAN	1974 STD	1974 NO	1975 MEAN	1975 STD	1975 NO	1976 MEAN	1976 STD	1976 NO	1977 MEAN	1977 STD	1977 NO
HAMILTON WWTP												.320	.320	12	.270	.150	9
BURLINGTON WWTP																	
STELCO HOT STRIP FINISHING		.010	.070		2												
STELCO EAST SIDE LAGOON		.460	.220		2												
STELCO OIL RECOVERY PLANT																	
STELCO 148 IN PLATE MILL		.640	.470		2												
STELCO NO 3 O.H. COOLING		.500	.200		2												
STELCO NORTH TRUNK		.440	.170		2												
STELCO WEST SIDE OPEN CUT		.400	.200		2												
STELCO NO 1 BSPH																	
STELCO NO 2 BSPH																	
STELCO COLD MILL TO CITY STORM		.150	.190		2												
STELCO NO 2 ROD MILL																	
STELCO ONTARIO WORKS 28 IN MIL																	
DOFASCO LAGOON OVERFLOW		.660	.210	.020	3												
DOFASCO COKE PLANT		.410	.180	.030	3												
DOFASCO OTTAWA STREET		.600	.200	.060	3												
DOFASCO BOILER HOUSE		.250	.150	.010	3												
DOFASCO BAY WATER INTAKE		.420	.120	.010	3												
STREAMS RED HILL CREEK															.100	.010	3
STREAMS GRINDSTONE															.043	.030	18
STREAMS BURLINGTON OPEN CHANNL															.029	.021	12
STREAMS FALCON CREEK																	
STREAMS ALDERSHOT DRAIN															.015	.002	12
STM OVERFLW 1 QUEEN																	
STM OVERFLW2 CAROLINE																	
STM OVERFLW 4 MARSHALL																	
STM OVERFLW 5 JAMES																	
STM OVERFLW 6,7,8 CATHER-WELLN																	
STM OVERFLW9 WENTWORTH																	
STM OVERFLW 11 BIRCH																	
STM OVERFLW 12 GAGE																	
STM OVERFLW 13 OTTAWA															.150	.060	8
STM OVERFLW 14 KENILWORTH															.100	.080	11
STM OVERFLW 15 STRATHEARNE															.170	.080	9
STM OVERFLW 16 PARKDALE															.091	.070	11
COOTES PARADISE									.086								

C O D

SOURCE	1971 MEAN	1972 MEAN	1973 MEAN	1973 STD	1973 NO	1974 MEAN	1974 STD	1974 NO	1975 MEAN	1975 STD	1975 NO	1976 MEAN	1976 STD	1976 NO	1977 MEAN	1977 STD	1977 NO
HAMILTON WWTP												109.000	31.000	12	78.900	13.900	12
BURLINGTON WWTP																	
STELCO HOT STRIP FINISHING	37.000	130.000	470.000		2	<20.000		1							<20.000		1
STELCO EAST SIDE LAGOON	30.000	30.000	30.000		2	<20.000		1	40.000		1	23.200	5.000	13	40.900	24.800	12
STELCO OIL RECOVERY PLANT												93.000	120.000	13	120.000	185.000	12
STELCO 148 IN PLATE MILL	30.000	28.000	37.000		2	<20.000		1	50.000		1						
STELCO NO 3 O.H. COOLING	30.000	30.000	30.000		2	<20.000		1	40.000		1	55.500			9.000	1.000	3
STELCO NORTH TRUNK	40.000	32.000	53.000		2	<20.000		1				24.000	15.600	13	25.900	10.600	12
STELCO WEST SIDE OPEN CUT	52.610	45.630	38.610			38.920			28.600			27.700	11.100	13	26.100	12.600	12
STELCO NO 1 BSPH	26.790	15.200	39.600			20.590			76.900						137.000	219.000	3
STELCO NO 2 BSPH	75.090	17.650	23.460			18.510			12.500			43.000			12.000	3.000	3
STELCO COLD MILL TO CITY STORM	870.000	35.000	120.000		2												
STELCO NO 2 ROD MILL																	
STELCO ONTARIO WORKS 28 IN MIL																	
DOFASCO LAGOON OVERFLOW	80.000	30.000	32.000	2.900	3				10.000		1	39.000		1	38.000	23.000	3
DOFASCO COKE PLANT	135.000	90.000	43.000	13.000	3				40.000		1	69.000		1	195.000	66.000	3
DOFASCO OTTAWA STREET	215.000	155.000	220.000	120.000	3				70.000		1	67.000		1	64.000	58.000	3
DOFASCO BOILER HOUSE	250.000	65.000	90.000	50.000	3				24.000		1	90.000		1	24.000	4.000	3
DOFASCO BAY WATER INTAKE	30.000	30.000	17.000	12.000	3				12.000		1	35.000		1	18.000	3.000	3
STREAMS RED HILL CREEK												53.000	23.000	31			
STREAMS GRINDSTONE															26.000	9.000	18
STREAMS BURLINGTON OPEN CHANNL															25.000	9.000	10
STREAMS FALCON CREEK																	
STREAMS ALDERSHOT DRAIN															28.000	9.000	10
STM OVERFLW 1 QUEEN																	
STM OVERFLW2 CAROLINE																	
STM OVERFLW 4 MARSHALL																	
STM OVERFLW 5 JAMES												26.400	5.500	28			
STM OVERFLW 6,7,8 CATHER-WELLN												38.500	23.400	77			
STM OVERFLW9 WENTWORTH												35.000	5.400	21			
STM OVERFLW 11 BIRCH												127.000	78.000	28			
STM OVERFLW 12 GAGE																	
STM OVERFLW 13 OTTAWA												308.000	6.000	28	416.000	712.000	7
STM OVERFLW 14 KENILWORTH												27.000	9.000	28	85.000	43.000	8
STM OVERFLW 15 STRATHEARNE												39.000	9.000	28	38.000	22.000	8
STM OVERFLW 16 PARKDALE												592.000	215.000	21	164.000	71.000	8
COOTES PARADISE									45.000								

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SOURCE	1971 MEAN	1972 MEAN	1973 MEAN	1973 STD	1973 NO	1974 MEAN	1974 STD	1974 NO	1975 MEAN	1975 STD	1975 NO	1976 MEAN	1976 STD	1976 NO	1977 MEAN	1977 STD	1977 NO
HAMILTON WWTP																	
BURLINGTON WWTP																	
STELCO HOT STRIP FINISHING																	
STELCO EAST SIDE LAGOON																	
STELCO OIL RECOVERY PLANT																	
STELCO 148 IN PLATE MILL																	
STELCO NO 3 O.H. COOLING																	
STELCO NORTH TRUNK																	
STELCO WEST SIDE OPEN CUT																	
STELCO NO 1 BSPH																	
STELCO NO 2 BSPH																	
STELCO COLD MILL TO CITY STORM																	
STELCO NO 2 ROD MILL																	
STELCO ONTARIO WORKS 29 IN MIL																	
DOFASCO LAGOON OVERFLOW																	
DOFASCO COKE PLANT																	
DOFASCO OTTAWA STREET																	
DOFASCO BOILER HOUSE																	
DOFASCO BAY WATER INTAKE																	
STREAMS RED HILL CREEK												10.000	2.000	31			
STREAMS GRINDSTONE																	
STREAMS BURLINGTON OPEN CHANNL															6.000	3.000	12
STREAMS FALCON CREEK																	
STREAMS ALDERSHOT DRAIN															6.000	2.000	12
STM OVERFLW 1 QUEEN																	
STM OVERFLW2 CAROLINE																	
STM OVERFLW 4 MARSHALL																	
STM OVERFLW 5 JAMES												6.500	1.200	28			
STM OVERFLW 6,7,8 CATHER-WELLI												6.900	1.500	28			
STM OVERFLW9 WENTWORTH												5.300	.900	21			
STM OVERFLW 11 BIRCH												14.500	7.200	28			
STM OVERFLW 12 GAGE																	
STM OVERFLW 13 OTTAWA												3.700	1.100	28	12.000	10.000	7
STM OVERFLW 14 KENILWORTH												4.700	1.000	28	5.000	7.000	8
STM OVERFLW 15 STRATHEARNE												6.100	2.100	28	7.000	15.000	8
STM OVERFLW 16 PARKDALE												46.000	15.000	21	31.000	13.000	8
COOTES PARADISE																	

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SOURCE	1971 MEAN	1972 MEAN	1973 MEAN	1973 STD	1973 NO	1974 MEAN	1974 STD	1974 NO	1975 MEAN	1975 STD	1975 NO	1976 MEAN	1976 STD	1976 NO	1977 MEAN	1977 STD	1977 NO
HAMILTON WWTP															31.100	10.800	8
BURLINGTON WWTP																	
STELCO HOT STRIP FINISHING		19.000	81.000		1												
STELCO EAST SIDE LAGOON		11.000	10.000		1												
STELCO OIL RECOVERY PLANT																	
STELCO 148 IN PLATE MILL		210.000	14.000		1												
STELCO NO 3 O.H. COOLING		10.000	10.000		1												
STELCO NORTH TRUNK		11.000	27.000		1												
STELCO WEST SIDE OPEN CUT		16.000	11.000		1												
STELCO NO 1 BSPH																	
STELCO NO 2 BSPH																	
STELCO COLD MILL TO CITY STORM		14.000	12.000		1												
STELCO NO 2 ROD MILL																	
STELCO ONTARIO WORKS 28 IN MIL																	
DOFASCO LAGOON OVERFLOW		850.000	11.000		2												
DOFASCO COKE PLANT		12.000	9.000		2												
DOFASCO OTTAWA STREET		6.000	40.000		2												
DOFASCO BOILER HOUSE		8.000	10.000		2												
DOFASCO BAY WATER INTAKE		430.000	9.000		2												
STREAMS RED HILL CREEK												21.000	11.000	31	5.000	2.000	5
STREAMS GRINDSTONE															13.000	5.000	21
STREAMS BURLINGTON OPEN CHANNL															10.000	5.000	16
STREAMS FALCON CREEK																	
STREAMS ALDERSHOT DRAIN															11.000	7.000	15
STM OVERFLW 1 QUEEN																	
STM OVERFLW2 CAROLINE																	
STM OVERFLW 4 MARSHALL																	
STM OVERFLW 5 JAMES												8.200	2.400	28			
STM OVERFLW 6,7,8 CATHER-WELLN												10.400	7.300	77			
STM OVERFLW9 WENTWORTH												6.700	1.000	21			
STM OVERFLW 11 BIRCH												92.000	321.000	28			
STM OVERFLW 12 GAGE																	
STM OVERFLW 13 OTTAWA												6.300	1.300	28	99.000	196.000	8
STM OVERFLW 14 KENILWORTH												6.600	2.400	28	23.000	17.000	14
STM OVERFLW 15 STRATHEARNE												9.300	3.300	28	16.000	9.000	8
STM OVERFLW 16 PARKDALE												*******	*******	21	49.000	34.000	14
COOTES PARADISE																	

B O D 5

SOURCE	1971 MEAN	1972 MEAN	1973 MEAN	1973 STD	1973 NO	1974 MEAN	1974 STD	1974 NO	1975 MEAN	1975 STD	1975 NO	1976 MEAN	1976 STD	1976 NO	1977 MEAN	1977 STD	1977 NO
HAMILTON WWTP	76.000	56.000	28.000			14.100			32.000			20.300	6.400	12	21.100	16.100	11
BURLINGTON WWTP	8.000	9.000	10.000			3.000			7.000			13.000			16.000		
STELCO HOT STRIP FINISHING		6.000	3.000		2	1.000		1	2.000		1				12.000		1
STELCO EAST SIDE LAGOON	9.000	6.000	5.000		2	2.000		1	5.000		1	11.000			10.200	.800	3
STELCO OIL RECOVERY PLANT												9.000			10.000	4.000	3
STELCO 148 IN PLATE MILL	6.000	9.000	10.000		2	3.000		1									
STELCO NO 3 O.H. COOLING	2.700		3.000		2	3.000		1	4.000		1	6.000			4.000	2.000	3
STELCO NORTH TRUNK	7.000	9.000	15.000		2	4.000		1	4.000		1	2.500			3.800	.600	3
STELCO WEST SIDE OPEN CUT	13.000	13.000	13.000		2	2.000		1	2.000		1	3.400			3.200	.300	3
STELCO NO 1 BSPH						1.000		1							1.500	.100	2
STELCO NO 2 BSPH						3.000		1	3.000		1	1.000			1.900	.900	3
STELCO COLD MILL TO CITY STORM	340.000	21.000	26.000		2	1.000		1									
STELCO NO 2 ROD MILL																	
STELCO ONTARIO WORKS 28 IN MIL																	
DOFASCO LAGOON OVERFLOW	32.000	7.000	5.000	3.600	3				1.400	1.000		11.000	4.900	12	15.200	4.400	12
DOFASCO COKE PLANT	42.000	39.000	21.000	3.600	3				10.000		1	15.300	1.620	12	25.900	13.300	12
DOFASCO OTTAWA STREET	60.000	63.000	83.000	60.000	3				16.000		1	26.700	6.500	12	26.600	5.500	12
DOFASCO BOILER HOUSE	50.000	40.000	11.000	4.400	3				5.000		1	13.500	1.200	10	15.200	9.400	11
DOFASCO BAY WATER INTAKE	3.000	9.000	3.000	1.500	3				1.600	1.000		13.100	4.100	12	17.600	3.900	12
STREAMS RED HILL CREEK			19.000			24.000						14.000	3.600	31	13.000	15.000	6
STREAMS GRINDSTONE			4.200			3.600									6.000	4.000	27
STREAMS BURLINGTON OPEN CHANNEL															5.000	4.000	16
STREAMS FALCON CREEK																	
STREAMS ALDERSHOT DRAIN															5.000	4.000	16
STM OVERFLW 1 QUEEN																	
STM OVERFLW2 CAROLINE																	
STM OVERFLW 4 MARSHALL																	
STM OVERFLW 5 JAMES												5.500	2.600	28			
STM OVERFLW 6,7,8 CATHER-WELLN												5.800	5.600	77			
STM OVERFLW9 WENTWORTH												5.300	.900	21			
STM OVERFLW 11 BIRCH												33.000	32.300	28			
STM OVERFLW 12 GAGE																	
STM OVERFLW 13 OTTAWA												3.900	1.300	28	6.000	7.000	3
STM OVERFLW 14 KENILWORTH												5.500	1.500	28	5.000	6.000	5
STM OVERFLW 15 STRATHEARNE												7.500	2.100	28			
STM OVERFLW 16 PARKDALE												345.000	46.300	21	16.000	29.000	6
COOTES PARADISE									7.800								

	CYANIDE		HCN														
	1971	1972	1973			1974			1975			1976			1977		
SOURCE	MEAN	MEAN	MEAN	STD	NO	MEAN	STD	NO	MEAN	STD	NO	MEAN	STD	NO	MEAN	STD	NO
HAMILTON WWTP																	
BURLINGTON WWTP																	
STELCO HOT STRIP FINISHING	.010	.010	<.100		2	<.010		1	.010		1				<.010		1
STELCO EAST SIDE LAGOON	.160	.420	.494			.095			.124			.100	.120	24	.163	.180	24
STELCO OIL FECOVERY PLANT												.060			.050	.060	3
STELCO 148 IN PLATE MILL	.010		2.100		2	<.010		1	.020		1						
STELCO NO 3 O.H. COOLING	.010	.010	.070		2	<.010		1	.010		1	.100			.030	.020	3
STELCO NORTH TRUNK	2.350	2.760	1.390			.679			1.240			2.400	6.100	24	2.900	7.300	24
STELCO WEST SIDE OPEN CUT	8.460	6.510	4.100			2.340			2.800			2.200	2.100	24	3.870	2.900	24
STELCO NO 1 BSPH	.030		.124			.141			.190			.030	.020	4	.041	.024	12
STELCO NO 2 BSPH	.340	.600	.140			.145			.250			.130	.180	12	.280	.160	12
STELCO COLD MILL TO CITY STORM	.050	.020	.150		2	.010		1									
STELCO NO 2 ROD MILL																	
STELCO ONTARIO WORKS 28 IN MIL																	
DOFASCO LAGOON OVERFLOW	1.140	.951	.420			.530			.280			.380	.220	12	.163	.094	12
DOFASCO COKE PLANT	2.940	.930	.580			.630			.370			.070	.180	12	.093	.110	12
DOFASCO OTTAWA STREET	.334	.180	.105			.160			.090			.029	.021	12	.018	.011	12
DOFASCO BOILER HOUSE			.069			.062			.030			.179	.400	12	.097	.206	11
DOFASCO BAY WATER INTAKE	.260	.160	.100			.080			.050			.033	.029	12	.016	.005	12
STREAMS RED HILL CREEK																	
STREAMS GRINDSTONE																	
STREAMS BURLINGTON OPEN CHANNL																	
STREAMS FALCON CREEK																	
STREAMS ALDERSHOT DRAIN																	
STM OVERFLW 1 QUEEN																	
STM OVERFLW2 CAROLINE																	
STM OVERFLW 4 MARSHALL																	
STM OVERFLW 5 JAMES																	
STM OVERFLW 6,7,8 CATHER-WELLN																	
STM OVERFLW9 WENTWORTH																	
STM OVERFLW 11 BIRCH																	
STM OVERFLW 12 GAGE																	
STM OVERFLW 13 OTTAWA																	
STM OVERFLW 14 KENILWORTH																	
STM OVERFLW 15 STRATHEARNE																	
STM OVERFLW 16 PARKDALE																	
COOTES PARADISE																	

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SOURCE	1971 MEAN	1972 MEAN	1973 MEAN	1973 STD	1973 NO	1974 MEAN	1974 STD	1974 NO	1975 MEAN	1975 STD	1975 NO	1976 MEAN	1976 STD	1976 NO	1977 MEAN	1977 STD	1977 NO
HAMILTON WWTP																	
BURLINGTON WWTP																	
STELCO HOT STRIP FINISHING	.010	.038	.276		2	.001		1							.004		1
STELCO EAST SIDE LAGOON	.117	.065	.056			.049			.046			.040	.039	24	.083	.109	24
STELCO OIL RECOVERY PLANT												.010			.023	.016	3
STELCO 148 IN PLATE MILL	.040	.006	.023		2	.001		1									
STELCO NO 3 O.H. COOLING	.030	.003	.030		1	.011		1				.090			.005	.002	3
STELCO NORTH TRUNK	.200	.009	.380		2	.193		1	.326			.501	.908	24	.645	.958	24
STELCO WEST SIDE OPEN CUT	.614	.570	.520			.163			.210			.320	.613	24	.479	.290	24
STELCO NO 1 BSPH		.005	.206			.051			.036			.141	.119	5	.097	.212	12
STELCO NO 2 BSPH	.051	.053	.044			.023			.030			.042	.051	12	.129	.202	12
STELCO COLD MILL TO CITY STORM		.004	.022		2	.002		1									
STELCO NO 2 ROD MILL																	
STELCO ONTARIO WORKS 28 IN MIL																	
DOFASCO LAGOON OVERFLOW	.041	.046	.004			.030			.010			.035	.075	12	.021	.014	12
DOFASCO COKE PLANT	.514	.950	.470			.275			.210			.109	.128	12	.085	.046	12
DOFASCO OTTAWA STREET	1.350	.160	.014			.035			.150			.032	.017	12	.059	.039	12
DOFASCO BOILER HOUSE			.006			.002						.026	.031	12	.076	.178	11
DOFASCO BAY WATER INTAKE	.004	.006	.002			.002			.006			.019	.013	12	.015	.026	12
STREAMS RED HILL CREEK															.003	.001	3
STREAMS GRINDSTONE															.008	.006	15
STREAMS BURLINGTON OPEN CHANNL															.001	.002	9
STREAMS FALCON CREEK																	
STREAMS ALDERSHOT DRAIN															.006	.002	9
STM OVERFLW 1 QUEEN																	
STM OVERFLW2 CAROLINE																	
STM OVERFLW 4 MARSHALL																	
STM OVERFLW 5 JAMES																	
STM OVERFLW 6,7,8 CATHER-WELLN																	
STM OVERFLW9 WENTWORTH																	
STM OVERFLW 11 BIRCH																	
STM OVERFLW 12 GAGE																	
STM OVERFLW 13 OTTAWA															.033	.022	6
STM OVERFLW 14 KENILWORTH															.014	.006	9
STM OVERFLW 15 STRATHEARNE															.045	.096	6
STM OVERFLW 16 PARKDALE															.091	.133	10
COOTES PARADISE																	

ETHER SOLUBLES

SOURCE	1971 MEAN	1972 MEAN	1973 MEAN	1973 STD	1973 NO	1974 MEAN	1974 STD	1974 NO	1975 MEAN	1975 STD	1975 NO	1976 MEAN	1976 STD	1976 NO	1977 MEAN	1977 STD	1977 NO
HAMILTON WWTP																	
BURLINGTON WWTP																	
STELCO HOT STRIP FINISHING	3.500	7.800	3.000		2				1.000		1						
STELCO EAST SIDE LAGOON	1.000	5.500	3.200		2				3.000		1	4.000					
STELCO OIL RECOVERY PLANT												13.000					
STELCO 148 IN PLATE MILL	3.000	4.000	2.500		2				2.000		1						
STELCO NO 3 O.H. COOLING		2.000	4.000		2				1.000		1	1.000					
STELCO NORTH TRUNK	2.000	4.000	3.100		2												
STELCO WEST SIDE OPEN CUT	1.000	3.000	1.000		2				1.000		1	1.000					
STELCO NO 1 BSPH												1.000					
STELCO NO 2 BSPH									1.000		1	1.000					
STELCO COLD MILL TO CITY STORM	2.900	.500	7.600		2												
STELCO NO 2 ROD MILL																	
STELCO ONTARIO WORKS 28 IN MIL																	
DOFASCO LAGOON OVERFLOW	2.010	1.380	.670			.833			3.500			2.890	.920	12	1.510	1.370	12
DOFASCO COKE PLANT	10.690	5.560	3.740			7.300			3.800			3.370	2.000	12	1.680	.800	12
DOFASCO OTTAWA STREET	49.770	151.900	22.920			30.300			27.200			7.000	6.600	12	1.570	.620	12
DOFASCO BOILER HOUSE		7.150	3.050			1.630			3.100			3.380	1.800	11	1.660	.680	11
DOFASCO BAY WATER INTAKE	1.560	1.390	.970			1.800			2.700			2.420	.800	12	1.530	.810	12
STREAMS RED HILL CREEK																	
STREAMS GRINDSTONE																	
STREAMS BURLINGTON OPEN CHANNL																	
STREAMS FALCON CREEK																	
STREAMS ALDERSHOT DRAIN																	
STM OVERFLW 1 QUEEN																	
STM OVERFLW2 CAROLINE																	
STM OVERFLW 4 MARSHALL																	
STM OVERFLW 5 JAMES																	
STM OVERFLW 6,7,8 CATHER-WELLN																	
STM OVERFLW9 WENTWORTH																	
STM OVERFLW 11 BIRCH																	
STM OVERFLW 12 GAGE																	
STM OVERFLW 13 OTTAWA																	
STM OVERFLW 14 KENILWORTH																	
STM OVERFLW 15 STRATHEARNE																	
STM OVERFLW 16 PARKDALE																	
COOTES PARADISE																	

CHLORIDE AND TDS

SOURCE	1971 MEAN	1972 MEAN	1973 MEAN	1973 STD	1973 NO	1974 MEAN	1974 STD	1974 NO	1975 MEAN	1975 STD	1975 NO	1976 MEAN	1976 STD	1976 NO	1977 MEAN	1977 STD	1977 NO
HAMILTON WWTP												157.000	44.000	12	157.000	51.000	7
BURLINGTON WWTP																	
STELCO HOT STRIP FINISHING	90.000	132.000	97.000		1										o 290.000		1
STELCO EAST SIDE LAGOON	55.000	62.000	67.000		1										o 337.000	16.000	3
STELCO OIL RECOVERY PLANT															o 359.000	25.000	3
STELCO 148 IN PLATE MILL	54.000	67.000	68.000		1												
STELCO NO 3 C.H. COOLING	54.000	65.000	67.000		1										o 329.000	16.000	3
STELCO NORTH TRUNK	60.000	76.000	71.000		1										o 337.000	15.000	3
STELCO WEST SIDE OPEN CUT	97.000	103.000	90.000		1										o 401.000	45.000	3
STELCO NO 1 BSPH															o 320.000	22.000	3
STELCO NO 2 BSPH	53.000														o 330.000	13.000	3
STELCO COLD MILL TO CITY STORM	80.000	80.000	120.000		1												
STELCO NO 2 ROD MILL																	
STELCO ONTARIO WORKS 28 IN. MIL																	
DOFASCO LAGOON OVERFLOW	65.000	79.000	81.000		2										o 348.000	33.000	3
DOFASCO COKE PLANT	72.000	67.000	70.000		2										o 371.000	72.000	3
DOFASCO OTTAWA STREET	53.000	105.000	80.000		2										o 487.000	208.000	3
DOFASCO BOILER HOUSE		73.000	99.000		2										o 375.000	46.000	3
DOFASCO BAY WATER INTAKE	52.000	64.000	66.000		2										o 322.000	17.000	3
STREAMS RED HILL CREEK			95.300	17.000	9	109.000		17	95.000	22.500	9	71.000	19.000	9	75.000	10.000	3
STREAMS GRINDSTONE			46.000												139.000	57.000	15
STREAMS BURLINGTON OPEN CHANNEL															182.000	42.000	15
STREAMS FALCON CREEK																	
STREAMS ALDERSHOT DRAIN															121.000	35.000	15
STM OVERFLW 1 QUEEN																	
STM OVERFLW2 CAROLINE																	
STM OVERFLW 4 MARSHALL																	
STM OVERFLW 5 JAMES																	
STM OVERFLW 6,7,8 CATHER-WELLI																	
STM OVERFLW9 WENTWORTH																	
STM OVERFLW 11 BIRCH																	
STM OVERFLW 12 GAGE																	
STM OVERFLW 13 OTTAWA															96.000		2
STM OVERFLW 14 KENILWORTH															55.000	19.000	6
STM OVERFLW 15 STRATHEARNE															33.000	6.000	6
STM OVERFLW 16 PARKDALE																	
COOTES PARADISE									51.000								

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CONDUCTIVITY

SOURCE	1971 MEAN	1972 MEAN	1973 MEAN	1973 STD	1973 NO	1974 MEAN	1974 STD	1974 NO	1975 MEAN	1975 STD	1975 NO	1976 MEAN	1976 STD	1976 NO	1977 MEAN	1977 STD	1977 NO
HAMILTON WWTP																	
BURLINGTON WWTP																	
STELCO HOT STRIP FINISHING																	
STELCO EAST SIDE LAGOON																	
STELCO OIL RECOVERY PLANT																	
STELCO 148 IN PLATE MILL																	
STELCO NO 3 O.H. COOLING																	
STELCO NORTH TRUNK																	
STELCO WEST SIDE OPEN CUT																	
STELCO NO 1 BSPH																	
STELCO NO 2 BSPH																	
STELCO COLD MILL TO CITY STORM																	
STELCO NO 2 ROD MILL																	
STELCO ONTARIO WORKS 28 IN MIL																	
DOFASCO LAGOON OVERFLOW																	
DOFASCO COKE PLANT																	
DOFASCO OTTAWA STREET																	
DOFASCO BOILER HOUSE																	
DOFASCO BAY WATER INTAKE																	
STREAMS RED HILL CREEK			916.000			943.000						780.000	47.000	63	933.000	21.000	3
STREAMS GRINDSTONE			642.000			681.000			708.000						600.000	66.000	17
STREAMS BURLINGTON OPEN CHANNL															800.000	101.000	8
STREAMS FALCON CREEK																	
STREAMS ALDERSHOT DRAIN															870.000	75.000	11
STM OVERFLW 1 QUEEN																	
STM OVERFLW2 CAROLINE																	
STM OVERFLW 4 MARSHALL																	
STM OVERFLW 5 JAMES												395.000	19.000	52			
STM OVERFLW 6,7,8 CATHER-WELLN												498.000	59.000	**			
STM OVERFLW9 WENTWORTH												533.000	12.000	39			
STM OVERFLW 11 BIRCH												540.000	55.000	49	560.000	23.000	3
STM OVERFLW 12 GAGE																	
STM OVERFLW 13 OTTAWA												501.000	23.000	49	760.000	40.000	3
STM OVERFLW 14 KENILWORTH												519.000	10.000	48	780.000	77.000	6
STM OVERFLW 15 STRATHEARNE												527.000	24.000	50	507.000	23.000	3
STM OVERFLW 16 PARKDALE												700.000	48.000	38	811.000	27.000	6
COOTES PARADISE									520.000								

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SOURCE	1971 MEAN	1972 MEAN	1973 MEAN	1973 STD	1973 NO	1974 MEAN	1974 STD	1974 NO	1975 MEAN	1975 STD	1975 NO	1976 MEAN	1976 STD	1976 NO	1977 MEAN	1977 STD	1977 NO
HAMILTON WWTP																	
BURLINGTON WWTP																	
STELCO HOT STRIP FINISHING												5.100	2.100	23	5.800	1.400	23
STELCO EAST SIDE LAGOON												7.200	.230	15	7.500	.460	23
STELCO OIL RECOVERY PLANT												7.800	.450	23	7.700	1.600	24
STELCO 148 IN PLATE MILL																	
STELCO NO 3 O.H. COOLING												7.800			8.100	.100	3
STELCO NORTH TRUNK												7.700	.360	3	8.100	.200	3
STELCO WEST SIDE OPEN CUT												7.200	2.800	2	7.900	.400	3
STELCO NO 1 BSPH												8.200			8.300	.100	3
STELCO NO 2 BSPH												7.900			6.400	2.900	3
STELCO COLD MILL TO CITY STORM												3.200	1.000	22	4.200	1.800	23
STELCO NO 2 ROD MILL												7.800		1			
STELCO ONTARIO WORKS 28 IN MIL												7.800		1			
DOFASCO LAGOON OVERFLOW												6.400	.240	12	8.700	.310	12
DOFASCO COKE PLANT												7.700	.210	12	7.900	.190	12
DOFASCO OTTAWA STREET												6.600	.600	12	7.300	.300	12
DOFASCO BOILER HOUSE												7.480	.320	12	8.100	.440	11
DOFASCO BAY WATER INTAKE												7.600	.460	12	7.800	.220	12
STREAMS RED HILL CREEK			7.900	.210	9	8.110	.180	17	7.820	.270	9	8.000	.040	9	7.700	.100	6
STREAMS GRINDSTONE															8.700	.500	18
STREAMS BURLINGTON OPEN CHANNL															8.200	.200	12
STREAMS FALCON CREEK																	
STREAMS ALDERSHOT DRAIN															8.200	.200	12
STM OVERFLW 1 QUEEN																	
STM OVERFLW2 CAROLINE																	
STM OVERFLW 4 MARSHALL																	
STM OVERFLW 5 JAMES																	
STM OVERFLW 6,7,8 CATHER-WELLN																	
STM OVERFLW9 WENTWORTH																	
STM OVERFLW 11 BIRCH																	
STM OVERFLW 12 GAGE																	
STM OVERFLW 13 OTTAWA															7.100	.600	3
STM OVERFLW 14 KENILWORTH															8.100	.400	6
STM OVERFLW 15 STRATHEARNE																	
STM OVERFLW 16 PARKDALE															7.800	.200	6
COOTES PARADISE									8.000								

SUSPENDED SOLIDS

SOURCE	1971 MEAN	1972 MEAN	1973 MEAN	1973 STD	1973 NO	1974 MEAN	1974 STD	1974 NO	1975 MEAN	1975 STD	1975 NO	1976 MEAN	1976 STD	1976 NO	1977 MEAN	1977 STD	1977 NO
HAMILTON WWTP	61.000	71.000	32.000			38.000			74.000			57.100			45.700	13.500	9
BURLINGTON WWTP	10.000	13.000	14.000			20.000			17.000			25.000			16.000		
STELCO HOT STRIP FINISHING	11.000	10.000	40.000		2	10.000		1	10.000		1	15.900	16.600	23	16.600	10.500	24
STELCO EAST SIDE LAGOON	30.000	45.000	70.000		2	30.000		1	40.000		1	40.300	24.300	23	66.000	14.000	3
STELCO OIL RECOVERY PLANT												54.800	61.100	24	54.100	69.600	24
STELCO 148 IN PLATE MILL	59.000	47.000	50.000		2	40.000		1	110.000		1						
STELCO NO 3 O.H. COOLING	8.000	28.000	60.000		2	10.000		1	10.000		1	11.300	7.000	12	9.100	11.100	12
STELCO NORTH TRUNK	25.000	40.000	50.000		2	20.000		1				14.700	7.500	24	16.200	9.100	24
STELCO WEST SIDE OPEN CUT	15.000	50.000	50.000		2	30.000		1	25.000		1	39.200	11.100	24	38.700	14.500	24
STELCO NO 1 BSPH												12.000	3.000	3	10.000	4.600	12
STELCO NO 2 BSPH	10.000											9.000	3.700	12	8.700	5.300	12
STELCO COLD MILL TO CITY STORM	290.000	40.000	90.000		2	30.000		1	10.000		1	15.300	8.500	24	16.600	13.600	24
STELCO NO 2 ROD MILL												43.800	16.700	12	38.000	24.300	12
STELCO ONTARIO WORKS 28 IN MIL												73.100	31.600	11	48.200	89.000	12
DOFASCO LAGOON OVERFLOW	28.750	22.170	19.660			22.100			27.700			65.300	25.700	12	76.600	30.100	12
DOFASCO COKE PLANT	31.160	21.340	16.160			22.500			14.700			13.500	8.100	12	9.600	2.900	12
DOFASCO OTTAWA STREET	116.500	161.000	117.000			120.100			95.800			75.900	26.800	12	84.200	33.000	12
DOFASCO BOILER HOUSE		47.320	39.710			12.700			20.300			23.200	18.000	12	19.000	16.700	11
DOFASCO BAY WATER INTAKE	15.010	10.960	7.760			6.500			10.400			9.900	3.200	12	11.200	7.500	12
STREAMS RED HILL CREEK			29.000			21.000	8.400	17	8.100	5.000	9	6.000	3.000	9	91.000	168.000	6
STREAMS GRINDSTONE			33.000												40.000	76.000	29
STREAMS BURLINGTON OPEN CHANNL															42.000	64.000	16
STREAMS FALCON CREEK																	
STREAMS ALDERSHOT DRAIN															23.000	76.000	16
STM OVERFLW 1 QUEEN																	
STM OVERFLW2 CAROLINE																	
STM OVERFLW 4 MARSHALL																	
STM OVERFLW 5 JAMES																	
STM OVERFLW 6,7,8 CATHER-WELLN																	
STM OVERFLW9 WENTWORTH																	
STM OVERFLW 11 BIRCH																	
STM OVERFLW 12 GAGE																	
STM OVERFLW 13 OTTAWA															142.000	129.000	3
STM OVERFLW 14 KENILWORTH															63.000	32.000	6
STM OVERFLW 15 STRATHEARNE																	
STM OVERFLW 16 PARKDALE															38.000	68.000	6
COOTES PARADISE									109.000								

TURBIDITY

SOURCE	1971 MEAN	1972 MEAN	1973 MEAN	1973 STD	1973 NO	1974 MEAN	1974 STD	1974 NO	1975 MEAN	1975 STD	1975 NO	1976 MEAN	1976 STD	1976 NO	1977 MEAN	1977 STD	1977 NO
HAMILTON WWTP																	
BURLINGTON WWTP																	
STELCO HOT STRIP FINISHING																	
STELCO EAST SIDE LAGOON																	
STELCO OIL RECOVERY PLANT																	
STELCO 148 IN PLATE MILL																	
STELCO NO 3 O.H. COOLING																	
STELCO NORTH TRUNK																	
STELCO WEST SIDE OPEN CUT																	
STELCO NO 1 BSPH																	
STELCO NO 2 BSPH																	
STELCO COLD MILL TO CITY STORM																	
STELCO NO 2 ROD MILL																	
STELCO ONTARIO WORKS 28 IN MIL																	
DOFASCO LAGOON OVERFLOW																	
DOFASCO COKE PLANT																	
DOFASCO OTTAWA STREET																	
DOFASCO BOILER HOUSE																	
DOFASCO BAY WATER INTAKE																	
STREAMS RED HILL CREEK			14.000			11.000									28.000	5.000	3
STREAMS GRINDSTONE			16.500			25.000			22.000						6.000	9.000	18
STREAMS BURLINGTON OPEN CHANNL															2.000	1.900	12
STREAMS FALCON CREEK																	
STREAMS ALDERSHOT DRAIN															1.700	.400	12
STM OVERFLW 1 QUEEN																	
STM OVERFLW2 CAROLINE																	
STM OVERFLW 4 MARSHALL																	
STM OVERFLW 5 JAMES																	
STM OVERFLW 6,7,8 CATHER-WELLN																	
STM OVERFLW9 WENTWORTH																	
STM OVERFLW 11 BIRCH																	
STM OVERFLW 12 GAGE																	
STM OVERFLW 13 OTTAWA															39.000	50.000	7
STM OVERFLW 14 KENILWORTH															26.000	14.000	11
STM OVERFLW 15 STRATHEARNE															13.000	13.000	8
STM OVERFLW 16 PARKDALE															32.000	13.000	11
COOTES PARADISE									44.000								

COLOUR

SOURCE	1971 MEAN	1972 MEAN	1973 MEAN	1973 STD	1973 NO	1974 MEAN	1974 STD	1974 NO	1975 MEAN	1975 STD	1975 NO	1976 MEAN	1976 STD	1976 NO	1977 MEAN	1977 STD	1977 NO
HAMILTON WWTP																	
BURLINGTON WWTP																	
STELCO HOT STRIP FINISHING																	
STELCO EAST SIDE LAGOON																	
STELCO OIL RECOVERY PLANT																	
STELCO 148 IN PLATE MILL																	
STELCO NO 3 O.H. COOLING																	
STELCO NORTH TRUNK																	
STELCO WEST SIDE OPEN CUT																	
STELCO NO 1 BSPH																	
STELCO NO 2 BSPH																	
STELCO COLD MILL TO CITY STORM																	
STELCO NO 2 ROD MILL																	
STELCO ONTARIO WORKS 28 IN MIL																	
DOFASCO LAGOON OVERFLOW																	
DOFASCO COKE PLANT																	
DOFASCO OTTAWA STREET																	
DOFASCO BOILER HOUSE																	
DOFASCO BAY WATER INTAKE																	
STREAMS RED HILL CREEK															40.000		3
STREAMS GRINDSTONE															34.000	12.000	8
STREAMS BURLINGTON OPEN CHANNL															15.000	6.000	12
STREAMS FALCON CREEK																	
STREAMS ALDERSHOT DRAIN															16.000	16.000	12
STM OVERFLW 1 QUEEN																	
STM OVERFLW2 CAROLINE																	
STM OVERFLW 4 MARSHALL																	
STM OVERFLW 5 JAMES																	
STM OVERFLW 6,7,8 CATHER-WELLN																	
STM OVERFLW9 WENTWORTH																	
STM OVERFLW 11 BIRCH																	
STM OVERFLW 12 GAGE																	
STM OVERFLW 13 OTTAWA															151.000	159.000	7
STM OVERFLW 14 KENILWORTH															72.000	41.000	11
STM OVERFLW 15 STRATHEARNE															49.000	34.000	8
STM OVERFLW 16 PARKDALE															88.000	35.000	11
COOTES PARADISE																	

ARSENIC AS

SOURCE	1971 MEAN	1972 MEAN	1973 MEAN	1973 STD	1973 NO	1974 MEAN	1974 STD	1974 NO	1975 MEAN	1975 STD	1975 NO	1976 MEAN	1976 STD	1976 NO	1977 MEAN	1977 STD	1977 NO
HAMILTON WWTP																	
BURLINGTON WWTP																	
STELCO HOT STRIP FINISHING															.004		1
STELCO EAST SIDE LAGOON												.010			.007	.002	3
STELCO OIL RECOVERY PLANT												<.002			.005	.003	3
STELCO 148 IN PLATE MILL																	
STELCO NO 3 O.H. COOLING												<.002			.001	.001	3
STELCO NORTH TRUNK												<.002			.002	.001	3
STELCO WEST SIDE OPEN CUT												<.002			.006	.005	3
STELCO NO 1 BSPH															.001		3
STELCO NO 2 BSPH												.001			.001	.001	3
STELCO COLD MILL TO CITY STORM																	
STELCO NO 2 ROD MILL																	
STELCO ONTARIO WORKS 28 IN MIL																	
DOFASCO LAGOON OVERFLOW												.004			.008	.003	3
DOFASCO COKE PLANT															.002	.001	3
DOFASCO OTTAWA STREET												< .002			.003	.001	2
DOFASCO BOILER HOUSE															.002	.001	3
DOFASCO BAY WATER INTAKE												<.001			.002	.001	3
STREAMS RED HILL CREEK																	
STREAMS GRINDSTONE																	
STREAMS BURLINGTON OPEN CHANNL																	
STREAMS FALCON CREEK																	
STREAMS ALDERSHOT DRAIN																	
STM OVERFLW 1 QUEEN																	
STM OVERFLW2 CAROLINE																	
STM OVERFLW 4 MARSHALL																	
STM OVERFLW 5 JAMES																	
STM OVERFLW 6,7,8 CATHER-WELLN																	
STM OVERFLW9 WENTWORTH																	
STM OVERFLW 11 BIRCH																	
STM OVERFLW 12 GAGE																	
STM OVERFLW 13 OTTAWA															.010	.002	4
STM OVERFLW 14 KENILWORTH															.002	.001	4
STM OVERFLW 15 STRATHEARNE															.001		4
STM OVERFLW 16 PARKDALE															.001	.001	4
COOTES PARADISE									.005								

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CADMIUM

SOURCE	1971 MEAN	1972 MEAN	1973 MEAN	1973 STD	1973 NO	1974 MEAN	1974 STD	1974 NO	1975 MEAN	1975 STD	1975 NO	1976 MEAN	1976 STD	1976 NO	1977 MEAN	1977 STD	1977 NO
HAMILTON WWTP															<.005		1
BURLINGTON WWTP																	
STELCO HOT STRIP FINISHING															<.005		1
STELCO EAST SIDE LAGOON												<.010			.003	.001	3
STELCO OIL RECOVERY PLANT												<.010			<.005		3
STELCO 148 IN PLATE MILL																	
STELCO NO 3 O.H. COOLING												<.010			<.005		3
STELCO NORTH TRUNK												<.010			<.005		3
STELCO WEST SIDE OPEN CUT												<.010			<.005		3
STELCO NO 1 BSPH												<.005			<.005		3
STELCO NO 2 BSPH												<.007			<.005		3
STELCO COLD MILL TO CITY STORM																	
STELCO NO 2 ROD MILL																	
STELCO ONTARIO WORKS 28 IN MIL																	
DOFASCO LAGOON OVERFLOW												<.010			<.005		3
DOFASCO COKE PLANT												<.010			<.005		3
DOFASCO OTTAWA STREET												<.010			<.005		2
DOFASCO BOILER HOUSE												<.010			<.005		3
DOFASCO BAY WATER INTAKE												<.010			<.005		3
STREAMS RED HILL CREEK															<.005		3
STREAMS GRINDSTONE															<.005		2
STREAMS BURLINGTON OPEN CHANNEL															<.005		2
STREAMS FALCON CREEK																	
STREAMS ALDERSHOT DRAIN															<.005		2
STM OVERFLW 1 QUEEN																	
STM OVERFLW2 CAROLINE																	
STM OVERFLW 4 MARSHALL																	
STM OVERFLW 5 JAMES																	
STM OVERFLW 6,7,8 CATHER-WELLN																	
STM OVERFLW9 WENTWORTH																	
STM OVERFLW 11 BIRCH																	
STM OVERFLW 12 GAGE																	
STM OVERFLW 13 OTTAWA															<.005		6
STM OVERFLW 14 KENILWORTH															<.005		11
STM OVERFLW 15 STRATHEARNE															<.005		8
STM OVERFLW 16 PARKDALE															<.005		11

COOTES PARADISE

CHROMIUM CR

SOURCE	1971 MEAN	1972 MEAN	1973 MEAN	1973 STD	1973 NO	1974 MEAN	1974 STD	1974 NO	1975 MEAN	1975 STD	1975 NO	1976 MEAN	1976 STD	1976 NO	1977 MEAN	1977 STD	1977 NO
HAMILTON WWTP															.150		1
BURLINGTON WWTP																	
STELCO HOT STRIP FINISHING		.040	560.000		2	<.030		1							<.040		1
STELCO EAST SIDE LAGOON		.060	55.000		2	<.033		1				<.020		1	.080	.010	3
STELCO OIL RECOVERY PLANT												<.020		1	.010	.010	3
STELCO 148 IN PLATE MILL		.040	<.010		2	<.030		1									
STELCO NO 3 C.H. COOLING		.040	.020		2	<.033		1				<.020		1	.010	.010	3
STELCO NORTH TRUNK		.040	.010		2	<.033		1				<.020		1	.010	.010	3
STELCO WEST SIDE OPEN CUT		<.040	<.010		2	<.033		1				<.020		1	.010	.100	3
STELCO NO 1 BSPH						<.033		1				<.020			.010	.010	3
STELCO NO 2 BSPH						<.033		1				<.020			.010	.010	3
STELCO COLD MILL TO CITY STORM		<.040	<.010		2	.350		1									
STELCO NO 2 ROD MILL																	
STELCO ONTARIO WORKS 28 IN MIL																	
DOFASCO LAGOON OVERFLOW	.460	.003	.030	.030	3				.030		1	<.020		1	.030	.010	3
DOFASCO COKE PLANT	.130	.010	.090	.050	3				.160		1	<.020		1	.090	.070	3
DOFASCO OTTAWA STREET	.650	.026	.460	.140	3				.050		1	<.020		1	.220	.130	2
DOFASCO BOILER HOUSE			.020	.010	3				.300		1	<.020		1	.020	.020	3
DOFASCO BAY WATER INTAKE	.054	.003	.010		3				.030		1	<.020		1	.010	.010	3
STREAMS RED HILL CREEK																	
STREAMS GRINDSTONE															<.020		2
STREAMS BURLINGTON OPEN CHANNL															.020	.010	2
STREAMS FALCON CREEK																	
STREAMS ALDERSHOT DRAIN															.020	.014	2
STM OVERFLW 1 QUEEN																	
STM OVERFLW2 CAROLINE																	
STM OVERFLW 4 MARSHALL																	
STM OVERFLW 5 JAMES																	
STM OVERFLW 6,7,8 CATHER-WELLN																	
STM OVERFLW9 WENTWORTH																	
STM OVERFLW 11 BIRCH																	
STM OVERFLW 12 GAGE																	
STM OVERFLW 13 OTTAWA															.560	.600	4
STM OVERFLW 14 KENILWORTH															.040	.010	4
STM OVERFLW 15 STRATHEARNE															.030	.010	4
STM OVERFLW 16 PARKDALE															.020	.020	4

COOTES PARADISE

COPPER

SOURCE	1971	1972	1973			1974			1975			1976			1977		
	MEAN	MEAN	MEAN	STD	NO	MEAN	STD	NO	MEAN	STD	NO	MEAN	STD	NO	MEAN	STD	NO
HAMILTON WWTP															.070	.400	8
BURLINGTON WWTP																	
STELCO HOT STRIP FINISHING															.440		1
STELCO EAST SIDE LAGOON												.050			.070	.020	3
STELCO OIL RECOVERY PLANT												.160			.090	.030	3
STELCO 148 IN PLATE MILL																	
STELCO NO 3 O.H. COOLING												.050			.030	.020	3
STELCO NORTH TRUNK												.030			.040	.030	3
STELCO WEST SIDE OPEN CUT												.030			.040	.010	3
STELCO NO 1 BSPH												.020			.030	.010	3
STELCO NO 2 BSPH												.035			.060	.050	3
STELCO COLD MILL TO CITY STORM																	
STELCO NO 2 ROD MILL																	
STELCO ONTARIO WORKS 28 IN MIL																	
DOFASCO LAGOON OVERFLOW												.040		1	.050	.020	3
DOFASCO COKE PLANT												.040		1	.050	.010	3
DOFASCO OTTAWA STREET												.060		1	.120	.090	2
DOFASCO BOILER HOUSE												.060		1	.060	.030	3
DOFASCO BAY WATER INTAKE												.030		1	.040	.020	3
STREAMS RED HILL CREEK															.010	.010	3
STREAMS GRINDSTONE															.010		2
STREAMS BURLINGTON OPEN CHANNL															.010		2
STREAMS FALCON CREEK																	
STREAMS ALDERSHOT DRAIN															.020		2
STM OVERFLW 1 QUEEN																	
STM OVERFLW2 CAROLINE																	
STM OVERFLW 4 MARSHALL																	
STM OVERFLW 5 JAMES																	
STM OVERFLW 6,7,8 CATHER-WELLN																	
STM OVERFLW9 WENTWORTH																	
STM OVERFLW 11 BIRCH																	
STM OVERFLW 12 GAGE																	
STM OVERFLW 13 OTTAWA															.110	.160	8
STM OVERFLW 14 KENILWORTH															.020	.010	11
STM OVERFLW 15 STRATHEARNE															<.020	.010	8
STM OVERFLW 16 PARKDALE															.050	.030	11
COOTES PARADISE									.022								

IRON

SOURCE	1971	1972	1973			1974			1975			1976			1977		
	MEAN	MEAN	MEAN	STD	NO	MEAN	STD	NO	MEAN	STD	NO	MEAN	STD	NO	MEAN	STD	NO
HAMILTON WWTP												2.670	1.700	11	1.180	.550	9
BURLINGTON WWTP																	
STELCO HOT STRIP FINISHING												14.100	11.600	23	13.200	6.900	22
STELCO EAST SIDE LAGOON	20.570	24.600	23.770			23.830			23.300			19.100	14.600	24	46.400	13.700	24
STELCO OIL RECOVERY PLANT						17.100			40.300			13.100	23.000	23	13.800	15.300	24
STELCO 148 IN PLATE MILL	23.050	36.110	21.800			21.440			22.200			30.600			30.600		
STELCO NO 3 O.H. COOLING	1.204	4.010	1.590			2.500			.739			.620		1	1.000	.730	
STELCO NORTH TRUNK	11.640	11.100	5.535			5.450			6.700			1.700		1	1.200	.700	3
STELCO WEST SIDE OPEN CUT	6.468	9.181	7.570			6.550			5.200			2.300		1	3.000	2.000	3
STELCO NO 1 BSPH	2.349	2.230	1.610			1.510			5.800			1.100			.550	.150	3
STELCO NO 2 BSPH	1.430	2.805	2.910			2.130			1.600			.500		1	.580	.350	3
STELCO COLD MILL TO CITY STORM												8.700	7.000	23	16.200	15.200	24
STELCO NO 2 ROD MILL																	
STELCO ONTARIO WORKS 28 IN MIL																	
DOFASCO LAGOON OVERFLOW	7.770	4.920	5.640			7.100			5.900			12.900	13.200	12	8.600	5.500	12
DOFASCO COKE PLANT	6.800	5.100	3.180			2.700			1.900			2.160	.820	12	1.560	.830	12
DOFASCO OTTAWA STREET	67.420	66.250	116.900			92.600						50.600	23.200	12	56.400	19.500	12
DOFASCO BOILER HOUSE			4.980			2.050			3.100			5.190	5.560	11	3.300	2.600	11
DOFASCO BAY WATER INTAKE	2.250	2.170	2.120			1.010			1.340			2.280	1.560	12	1.980	1.300	12
STREAMS RED HILL CREEK																	
STREAMS GRINDSTONE															.150	.040	2
STREAMS BURLINGTON OPEN CHANNL															.130	.070	2
STREAMS FALCON CREEK																	
STREAMS ALDERSHOT DRAIN															.360	.060	2
STM OVERFLW 1 QUEEN																	
STM OVERFLW2 CAROLINE																	
STM OVERFLW 4 MARSHALL																	
STM OVERFLW 5 JAMES																	
STM OVERFLW 6,7,8 CATHER-WELLN																	
STM OVERFLW9 WENTWORTH																	
STM OVERFLW 11 BIRCH																	
STM OVERFLW 12 GAGE																	
STM OVERFLW 13 OTTAWA															48.000	27.000	4
STM OVERFLW 14 KENILWORTH															3.700	1.600	4
STM OVERFLW 15 STRATHEARNE															.840	.420	4
STM OVERFLW 16 PARKDALE															1.300	1.100	4
COOTES PARADISE									3.380								

LEAD

SOURCE	1971 MEAN	1972 MEAN	1973 MEAN	1973 STD	1973 NO	1974 MEAN	1974 STD	1974 NO	1975 MEAN	1975 STD	1975 NO	1976 MEAN	1976 STD	1976 NO	1977 MEAN	1977 STD	1977 NO
HAMILTON WWTP																	
BURLINGTON WWTP															.040	.020	8
STELCO HOT STRIP FINISHING															<.030		1
STELCO EAST SIDE LAGOON												.010			.020	.010	3
STELCO OIL RECOVERY PLANT												.030			.020	.020	3
STELCO 148 IN PLATE MILL																	
STELCO NO 3 O.H. COOLING												.020			.010	.010	3
STELCO NORTH TRUNK												.020			.020	.010	3
STELCO WEST SIDE OPEN CUT												.110			.040	.020	3
STELCO NO 1 BSPH												.010			.010	.010	3
STELCO NO 2 BSPH												.025			.010	.010	3
STELCO COLD MILL TO CITY STORM																	
STELCO NO 2 ROD MILL																	
STELCO ONTARIO WORKS 28 IN MIL																	
DOFASCO LAGOON OVERFLOW															.030	.030	3
DOFASCO COKE PLANT															.010	.010	3
DOFASCO OTTAWA STREET															.040	.040	2
DOFASCO BOILER HOUSE															.020	.010	3
DOFASCO BAY WATER INTAKE															.020	.001	3
STREAMS RED HILL CREEK															<.030		3
STREAMS GRINDSTONE															<.030		2
STREAMS BURLINGTON OPEN CHANNEL															<.030		2
STREAMS FALCON CREEK																	
STREAMS ALDERSHOT DRAIN															<.030		2
STM OVERFLW 1 QUEEN																	
STM OVERFLW2 CAROLINE																	
STM OVERFLW 4 MARSHALL																	
STM OVERFLW 5 JAMES																	
STM OVERFLW 6,7,8 CATHER-WELLI																	
STM OVERFLW9 WENTWORTH																	
STM OVERFLW 11 BIRCH																	
STM OVERFLW 12 GAGE																	
STM OVERFLW 13 OTTAWA															.030	.040	8
STM OVERFLW 14 KENILWORTH															.130	.320	11
STM OVERFLW 15 STRATHEARNE															<.030	.010	8
STM OVERFLW 16 PARKDALE															.050	.080	11
COOTES PARADISE																	

MANGANESE MN

SOURCE	1971 MEAN	1972 MEAN	1973 MEAN	1973 STD	1973 NO	1974 MEAN	1974 STD	1974 NO	1975 MEAN	1975 STD	1975 NO	1976 MEAN	1976 STD	1976 NO	1977 MEAN	1977 STD	1977 NO
HAMILTON WWTP															.130		1
BURLINGTON WWTP																	
STELCO HOT STRIP FINISHING															.140		1
STELCO EAST SIDE LAGOON												.260			.280	.060	3
STELCO OIL RECOVERY PLANT												.230			.160	.100	3
STELCO 148 IN PLATE MILL																	
STELCO NO 3 O.H. COOLING												.220			.100	.070	3
STELCO NORTH TRUNK												.400			.370	.150	3
STELCO WEST SIDE OPEN CUT												.620			1.100	.800	3
STELCO NO 1 BSPH												.060			.060	.020	3
STELCO NO 2 BSPH												.183			.140	.080	3
STELCO COLD MILL TO CITY STORM																	
STELCO NO 2 ROD MILL																	
STELCO ONTARIO WORKS 26 IN MIL																	
DOFASCO LAGOON OVERFLOW												.690		1	.660	.390	3
DOFASCO COKE PLANT												.140		1	.090	.040	3
DOFASCO OTTAWA STREET												.300		1	.170	.150	2
DOFASCO BOILER HOUSE												.290		1	.090	.030	3
DOFASCO BAY WATER INTAKE												.090		1	.070	.020	3
STREAMS RED HILL CREEK																	
STREAMS GRINDSTONE															.100	.110	2
STREAMS BURLINGTON OPEN CHANNL															.020		2
STREAMS FALCON CREEK																	
STREAMS ALDERSHOT DRAIN															.090	.100	2
STM OVERFLW 1 QUEEN																	
STM OVERFLW2 CAROLINE																	
STM OVERFLW 4 MARSHALL																	
STM OVERFLW 5 JAMES																	
STM OVERFLW 6,7,8 CATHER-WELLN																	
STM OVERFLW9 WENTWORTH																	
STM OVERFLW 11 BIRCH																	
STM OVERFLW 12 GAGE																	
STM OVERFLW 13 OTTAWA															.480	.340	4
STM OVERFLW 14 KENILWORTH															.790	.540	4
STM OVERFLW 15 STRATHEARNE															.030	.040	4
STM OVERFLW 16 PARKDALE															.110	.010	4
COOTES PARADISE									.250								

NICKEL NI

SOURCE	1971 MEAN	1972 MEAN	1973 MEAN	1973 STD	1973 NO	1974 MEAN	1974 STD	1974 NO	1975 MEAN	1975 STD	1975 NO	1976 MEAN	1976 STD	1976 NO	1977 MEAN	1977 STD	1977 NO
HAMILTON WWTP															.050		1
BURLINGTON WWTP																	
STELCO HOT STRIP FINISHING																	
STELCO EAST SIDE LAGOON																	
STELCO OIL RECOVERY PLANT																	
STELCO 148 IN PLATE MILL																	
STELCO NO 3 O.H. COOLING																	
STELCO NORTH TRUNK																	
STELCO WEST SIDE OPEN CUT																	
STELCO NO 1 ESPH																	
STELCO NO 2 ESPH																	
STELCO COLD MILL TO CITY STORM																	
STELCO NO 2 ROD MILL																	
STELCO ONTARIO WORKS 28 IN MIL																	
DOFASCO LAGOON OVEFFLOW																	
DOFASCO COKE PLANT																	
DOFASCO OTTAWA STREET																	
DOFASCO BOILER HOUSE																	
DOFASCO BAY WATER INTAKE																	
STREAMS RED HILL CREEK															.020	.010	3
STREAMS GRINDSTONE															<.020		2
STREAMS BURLINGTON OPEN CHANNEL															<.020		2
STREAMS FALCON CREEK																	
STREAMS ALDERSHOT DRAIN															<.020		2
STM OVERFLW 1 QUEEN																	
STM OVERFLW2 CAROLINE																	
STM OVERFLW 4 MARSHALL																	
STM OVERFLW 5 JAMES																	
STM OVERFLW 6,7,8 CATHER-WELLN																	
STM OVERFLW9 WENTWORTH																	
STM OVERFLW 11 BIRCH																	
STM OVERFLW 12 GAGE																	
STM OVERFLW 13 OTTAWA															.050	.040	8
STM OVERFLW 14 KENILWORTH															<.020	.010	11
STM OVERFLW 15 STRATHEARNE															<.020	.010	8
STM OVERFLW 16 PARKDALE															.010	.020	11
COOTES PARADISE																	

ZINC

SOURCE	1971 MEAN	1972 MEAN	1973 MEAN	1973 STD	1973 NO	1974 MEAN	1974 STD	1974 NO	1975 MEAN	1975 STD	1975 NO	1976 MEAN	1976 STD	1976 NO	1977 MEAN	1977 STD	1977 NO
HAMILTON WWTP															.340	.080	8
BURLINGTON WWTP																	
STELCO HOT STRIP FINISHING	.100	.140	.235		2	.030		1							.270		1
STELCO EAST SIDE LAGOON	.190	.120	.510		2	.080		1				.410			.300	.020	3
STELCO OIL RECOVERY PLANT												.760			.190	.110	3
STELCO 14B IN PLATE MILL	.200	.150	.330		2	.070		1									
STELCO NO 3 O.H. COOLING	.180	.160	.190		2	.100		1				1.700			.120	.040	3
STELCO NORTH TRUNK	2.000	.350	.600		2	.180		1				.530			.370	.150	3
STELCO WEST SIDE OPEN CUT	.900	1.200	1.800		2	2.300		1				3.700			4.900	1.500	3
STELCO NO 1 ESPH						.070		1				.110			.090	.030	3
STELCO NO 2 BSPH	.160					.150		1				.580			.340	.140	3
STELCO COLD MILL TO CITY STORM	.530	.410	.420		2	.200		1									
STELCO NO 2 ROD MILL																	
STELCO ONTARIO WORKS 28 IN MIL																	
DOFASCO LAGOON OVERFLOW	.210	.220	.410	.510	3				.210		1	.340		1	.340	.300	3
DOFASCO COKE PLANT	.050	.140	.430	.190	3				.120		1	.270		1	.070	.020	3
DOFASCO OTTAWA STREET	.010	.680	.240	.240	3				.070		1	.600		1	.140	.020	2
DOFASCO BOILER HOUSE		6.700	3.000	2.500	3				.160		1	.270		1	.080	.040	3
DOFASCO BAY WATER INTAKE	.060	.540	.010		3				.100		1	.150		1	.070	.020	3
STREAMS RED HILL CREEK															.020	.010	3
STREAMS GRINDSTONE															<.020		2
STREAMS BURLINGTON OPEN CHANNL															<.020		2
STREAMS FALCON CREEK																	
STREAMS ALDERSHOT DRAIN															<.020		2
STM OVERFLW 1 QUEEN																	
STM OVERFLW2 CAROLINE																	
STM OVERFLW 4 MARSHALL																	
STM OVERFLW 5 JAMES																	
STM OVERFLW 6,7,8 CATHER-WELLN																	
STM OVERFLW9 WENTWORTH																	
STM OVERFLW 11 BIRCH																	
STM OVERFLW 12 GAGE																	
STM OVERFLW 13 OTTAWA															4.000	10.900	6
STM OVERFLW 14 KENILWORTH															.210	.230	11
STM OVERFLW 15 STRATHEARNE															.320	.450	8
STM OVERFLW 16 PARKDALE															.290	.140	11
COOTES PARADISE									.065								

APPENDIX B

LOADINGS IN 1977 FROM STORM SEWERS TO

HAMILTON HARBOUR

APPENDIX B

LOADINGS IN 1977 FROM STORM SEWERS TO HAMILTON HARBOUR

Table B.1 presents a statistical summary of all 6-hour sampling runs performed at storm water outfalls in Hamilton Harbour during 1977. It was hoped to obtain loading data at these outfalls during periods of rain as well as clear weather, in order to obtain good estimates of storm sewer loading under such conditions; however, conditions of rainfall occurred on only a few occasions during or just before the sampling process. For dates on which measurable flow was observed, loading estimates were calculated from the mean data in Table B.1 and flows in m^3s^{-1}. The results are given in Table B.2.

It should be emphasized that the figures in Table B.2 are only order of magnitude estimates specific for the dates indicated, due to the difficulties encountered in measuring flows. The flows obtained were estimated from currents measured in the slip for each survey by drogue tracking and from the cross sectional area of each channel or sewer outfall, as follows. At locations 82 (James), 99 (Catherine), 121 (Wentworth), 211 (Kenilworth), 220 (Strathearne) and 225 (Parkdale), the cross sectional area of the sewer as indicated in City of Hamilton plans was multiplied by the measured current next to the outfall. The error caused by measuring the current in the slip (lower current than in the sewer) is assumed to be offset by the error involved in assuming that the sewer was full (too high a cross section). In the Ottawa and Kenilworth St. slips, the cross section was measured in the field and divided into upper and lower portions according to the temperature-depth profiles. Similarly, at location 273 (Birch), a cross-section measured in the field was used. At location 103 (Ferguson), the discharge is directly to the harbour. Thus measured currents are representative of harbour conditions; consequently no flow and loading estimates are available. At location 108, the sewer dimensions were not available and no loadings were calculated. At location 274 (Red Hill Creek), an estimated cross sectional area was used, assuming an average water depth of 1 m. The shallow nature of the creek made flow measurement difficult to impossible; however the loadings which were obtained were of a similar order of magnitude to results from the Hamilton STP.

On the basis of concentrations alone, the most concentrated effluents entered the harbour at locations 108, 273, 211, 225, and 274 (see Table B.1). Of these locations, the result at 108 was directly influenced by rainfall during the monitoring period. More will be said later. Location 274 is Red Hill Creek, which contains the Hamilton WWTP effluent, while the other three locations all contain industrial wastes. These latter four locations were not, unfortunately, observed under conditions of storm runoff, and thus the effect of runoff is not known.

The largest measured loadings occurred, as expected, at the Ottawa and Kenilworth St. slips and Red Hill Creek (Hamilton STP). Flows and dissolved solids loadings from the Ottawa and Kenilworth St. slips were about 5 and 14 times higher than results input to the numerical model using 1974 data, respectively. This may indicate large variations in flow across the openings of these slips which were not detected during surveys (which were not under rain conditions at these locations). As these locations contain mostly industrial discharges, it would be expected that the industrial figures measured at the outfalls would be more accurate.

The maximum flow and pollutant loading occurred on August 8 at location 108 a result of a brief rainfall during sampling. According to visual observations and Royal Botanical Gardens rain gauge data, the most intense rainfall lasted approximately 1/2 hour, and the total amount and duration of rainfall was 16.8 mm in 2 hours. Figure B.1 shows conductivity and organic pollutants as a function of time. Measured flows during runoff varied from 22 to 126 cm/s and were so strong that accurate conductivity measurements were impossible (the probe floated on the surface of the water). A direct response of BOD, COD, and TOC is shown, which lasted even after the rainfall had subsided. Conductivity values after the runoff indicated that a cleaner water (with respect to ionic salts) was being discharged. Correlations between COD and TOC was significant at the 99% level, but the other parameters were not statistically related. Estimated loadings in Table B.2 based on the flow occurring for one day indicate the possible magnitude of runoff from an extended rainfall, although it should be kept in mind that the storm water quality should improve with time during an extended runoff.

Figure B.2 shows a record obtained at location 103 at the same time. The outfall at this location discharges directly to the harbour; hence, no loading figures were possible, but the effect of the storm water runoff was visible as a conductivity peak which lasted for only 10 minutes and was followed by variable conditions including results below that expected for Hamilton Harbour. This indicated mixing of harbour water with runoff water of lower ionic concentration. All indicators of organic pollution correlated very highly with one another during this brief event.

Minor amounts of rainfall occurred during sampling on June 28 (locations 82 and 121) and August 8 (locations 220 and 273). However, the amount of rainfall in each case was 1.0 mm or less, and was not sufficient to have any detectable effect on the results.

Several other records of storm outfall water quality data obtained under dry weather conditions are presented in Figures B.3 to 6 for comparison. Figure B.3 illustrates results for location 103 (outfall to side of harbour) on July 25. The interesting fact is the large rapid conductivity changes, which occurred with large variations or intercorrelations in organic parameters. The latter is in contrast to the highly significant (P 99%) correlations observed under runoff at the same point as described above.

Figure B.4 shows results obtained at location 273 on August 10. Significant correlations (P 95%) were observed between BOD, COD, and TOC; with FOC only the relationship to TOC was significant. The high correlations are presumed due to the industrial waste being discharged at this location; higher correlations between these parameters are more usual in the case of wastewater streams compared to natural waters (Chandler et al, 1976).

Figure B.5 shows results obtained at location 220 on August 3. There is an apparent periodicity in conductivity of about 0.4 hour, which was not observed on other runs at this point. No significant correlations at the 95% level were obtained, although COD and TOC were related at the 90% level. This location receives significant industrial waste input, and on another occasion (August 10), produced a significant waste loading to the harbour.

Figure B.6 presents a typical result obtained at the Burlington St. bridge over Red Hill Creek. Water being carried at this point is primarily Hamilton STP effluent, BOD and TOC produced a significant (P 95%) correlation; FOC failed to correlate despite averaging 82% of TOC. It seems that the biochemical oxygen demand is being exerted by the particulate matter in this location; however, on other sampling dates none of the organic pollution indicaters correlated significantly with one another and it thus appears that the wastewater effluent plus other contributions to the creek contain water of highly variable characteristics.

The results obtained in this program provide an adequate description of the sites monitored in the absence of runoff. However, further data are needed to describe the effect of runoff on all locations; the importance of runoff is shown in the data (Figures B.1-B.2) for locations 108 and 103 on August 8. Of particular interest is the spring (March-May) period, when 60% of all runoff occurs. Future studies should emphasize the definition of runoff loadings for this peak period.

TABLE B.1
1977 HAMILTON HARBOUR STORM OUTFALL RESULTS

		BOD		COD		TOC		FOC		DO		CONDUCTIVITY (umho/cm)	
STATION	DATE	MEAN	SD	MEAN	SD	MEAN	SD	MEAN	SD	MEAN	SD	MEAN	SD
82	June 22	5.0	2.7	17	4	7.9	4.1	7.0	1.0	5.1	0.5	465	19
	June 28*	10.7	4.3	37	7	9.7	1.4	7.7	1.4	5.6	0.5	440	11
	July 27	4.3	1.1	28	5	8.6	1.4	6.1	1.5	9.4	1.5	485	5
	Aug. 9**	2.3	0.3	23	5	6.4	1.4	5.3	0.5	7.9	0.5	510	37
99	June 22	4.0	2.1	17	8	9.1	3.2	6.6	0.5	8.5	0.9	589	9
	July 27	4.9	1.0	28	2	5.3	1.5	5.3	1.5	9.2	1.8	480	5
	Aug. 9**	3.1	0.3	20	4	6.9	2.3	5.4	1.0	10.1	1.8	430	7
103	June 21	10.9	5.2	18	8	9.0	3.2	8.6	2.5	4.8	1.1	470	107
	July 25	1.0	0.7	38	4	8.7	1.1	6.4	1.0	8.3	0.6	555	62
	Aug. 2	2.4	0.4	26	3	8.7	1.0	6.4	1.4	7.3	0.5	457	33
	Aug. 8	5.5	7.1	59	29	11.9	10.5	6.6	2.6	8.2	1.4	478	123
108	June 21	8.1	0.8	37	8	7.7	1.3	7.7	1.3	5.1	0.3	622	17
	July 25	1.0	0.2	38	5	8.8	2.1	6.7	0.8	7.1	1.2	475	13
	Aug. 2	5.5	1.7	33	5	12	2	6.9	0.7	4.1	0.9	575	43
	Aug. 8*	18.0	16.0	109	70	26	21	9.0	1.0	5.0	0.5	510	100
121	June 28*	4.6	1.1	37	5	8.0	0.9	7.0	0.6	5.4	0.9	587	10
	July 5	9.0	1.0	24	5	6.0	1.0	5.0	1.0	8.1	1.2	525	12
	Aug. 6**	2.4	0.2	45	6	6.0	1.0	4.0	1.0	5.8	1.6	470	13
273	July 4	46.0	11.0	167	22	32	8	17	5	0.9	0.9	754	58
	July 18	58.0	63.0	258	154	314	641	21	13	0.8	0.9	590	73
	Aug. 4	16.0	7.0	44	8	13	3	12	3	2.5	0.9	495	38
	Aug. 10*	11.9	6.6	38	7	9	3	8	2	3.4	0.9	400	51

CON'T OF TABLE B.1

		BOD		COD		TOC		FOC		DO		CONDUCTIVITY (umho/cm)	
STATION	DATE	MEAN	SD	MEAN	SD	MEAN	SD	MEAN	SD	MEAN	SD	MEAN	SD
250 (0.5 metres)	July 11	3.8	0.5	37	8	6.7	2.1	3.4	1.0	5.7	0.7	653	39
	Aug. 11**	4.1	1.7	27	6	6.3	1.1	4.5	1.0	6.7	0.4	433	23
250 (2.0 metres)	July 11	5.3	1.8	34	4	6.1	0.7	2.9	0.7	5.8	0.4	525	17
	Aug. 11**	2.2	0.4	25	3	6.0	0.8	4.1	1.6	8.6	0.7	440	9
212 (0.5 metres)	July 8**	7.5	1.5	33	5	6.3	1.8	4.5	1.4	2.3	0.6	565	7
	Aug. 15	3.3	2.0	24	12	7.3	1.0	5.0	0.0	5.7	0.3	530	11
212 (2.0 metres)	Aug. 15	2.9	0.6	22	9	7.7	4.2	5.0	0.8	5.5	0.3	518	8
212 (5.0 metres)	July 8**	8.2	1.5	29	7	4.9	1.2	4.3	1.1	1.3	0.3	525	15
211	July 12	44	19	128	32	28	9	12	4	3.9	1.3	805	28
	July 22	32	10	308	138	112	64	35	22	0.6	0.5	940	72
	Aug. 4	101	21	247	44	62	16	37	6	5.3	0.2	1235	-
220	June 16	12.5	2.3	40	10	14	6	11	4	9.9	1.7	550	18
	July 16	3.5	0.6	38	9	4.0	2	4.0	1.0	6.6	0.7	580	31
	Aug. 3	7.0	3.0	40	9	10	2	9.0	1.0	4.6	1.5	530	22
	Aug. 10*	7.0	1.5	37	9	9.0	2	8.0	1.0	5.4	1.8	570	28

CON'T OF TABLE B.1

STATION	DATE	BOD MEAN	BOD SD	COD MEAN	COD SD	TOC MEAN	TOC SD	FOC MEAN	FOC SD	DO MEAN	DO SD	CONDUCTIVITY (umho/cm) MEAN	CONDUCTIVITY (umho/cm) SD
225	June 27	121	16	446	73	146	41	47	10	1.3	1.2	660	24
	July 20	105	41	395	149	3723	2355	33	5	0.4	0.5	850	29
	Aug. 3	208	67	936	334	354	111	57	24	0.6	0.6	840	76
274	June 15	53.3	11.5	87	77	53	37	10	3	1.9	1.8	800	56
	June 27	4.1	0.7	45	7	13	2	9	2	6.3	0.4	1000	-
	July 14	7.5	2.9	48	5	17	1	15	2	3.6	0.4	955	25
	July 22	1.3	1.2	41	16	11	2	9	1	4.4	1.8	630	76
	Aug. 11*	2.6	0.8	44	6	13	3	9	1	5.0	0.3	860	26

Note: All concentrations except conductivity are in mg/L.
* indicates rain occurred on day of sampling.
** indicates rain occurred on day before sampling.

TABLE B.2
ESTIMATES OF STORM SEWER OUTFALL LOADINGS
HAMILTON HARBOUR 1977

STATION	DATE	FLOW m^3/s	LOADING (10^3 kg/day) BOD	COD	TOC	FOC	DI SO
82	June 28	0.15	0.14	0.5	0.12	0.09	
	Aug. 9	0.013	0.003	0.03	0.01	0.01	
99	June 22	0.028	0.01	0.04	0.02	0.02	
121	Aug. 6	0.20	0.04	0.8	0.10	0.07	
273	July 4	0.3	1	4	0.8	0.4	
	July 18	0.7	4	20	20	1	
	Aug. 4	0.5	0.7	2	0.6	0.5	
	Aug. 10	0.6	0.6	2	0.5	0.4	
250 (surf.)	July 11	8	3	30	5	2	
	Aug. 11	9	3	20	5	3	
250 (Bottom)	July 11	57	30	170	30	10	
	Aug. 11	68	10	150	30	20	
212 (surf.)	July 8	6	4	20	3	2	
	Aug. 15	10	2	20	6	4	
212 (Bottom)	July 8	22	20	50	9	8	
	July 15	40	7	50	17	10	
211	July 12	0.12	0.5	1.3	0.3	0.1	
	July 22	0.07	0.2	1.9	0.7	0.2	
	Aug. 4	0.11	1.0	2.3	0.6	0.3	
220	Aug. 10	0.27	0.16	0.86	0.21	0.1	
225	June 27	0.11	1.1	4.2	1.4	0.	
	July 20	0.08	0.7	2.7	26	0.	
	Aug. 3	0.20	3.6	16	6.1	1.	
274	July 14	5	3	20	7	6	
	July 22	4	0.4	10	4	3	
	Aug. 11	1	0.2	4	1	0	

APPENDIX C

WATER QUALITY DATA ON VARIOUS STREAMS

IN THE

HAMILTON HARBOUR WATERSHED

1966 - 1976

TABLE C.1

AVERAGE WATER QUALITY DATA FOR GRINDSTONE AND RED HILL CREEKS (1)

GRINDSTONE CREEK

	BOD_5	TP	SP mg/L	NH_3	TKN	Cl	SS	Turb. FTU	Cond uS/cm
1969	3.8	0.22	0.06	0.18	1.5	32	43	49	604
1973	4.2	0.16	0.04	0.21	1.4	46	33	19	640
1974	3.6	0.17	0.05	0.17	1.3	-	-	25	680
1975	3.9	0.18	0.06	0.18	1.3	-	-	22	708
RED HILL CREEK									
1969	37	2.1	0.54	-	10.3	92	48	38	790
1973	19	1.2	0.4	13	17.4	116	29	14	920
1974	24	0.84	0.27	14	18	-	21	11	940

(1) From West Central Region Office, MOE

TABLE C.2

AVERAGE WATER QUALITY DATA FOR REDHILL CREEK*

DATE	MILE	N	Col./ 100 mL	F.Col./ 100 mL	NH_3 mg/L	NO_3 mg/L	TP mg/L	SP mg/L	pH	Alk mg/L	Hard mg/L	Cl mg/l	F mg/L	COD mg/L
1968 Jan-Oct	8.7	23	2,500	360	0.65	0.90	0.22	0.17	8.17	198	379	67	0.57	10
					(.57)	(.90)	(.14)	(.15)	(.28)	(32)	(60)	(11)	(.11)	(4)
	6.7	20	2,300	190	0.08	0.13	0.17	0.11	8.24	189	350	95	0.49	8
					(.13)	(.26)	(.12)	(.08)	(.27)	(45)	(54)	(18)	(.09)	(6)
	6.0	23	4,000	1200	8.04	0.29	0.19	0.12	8.09	317	473	166	0.51	25
					(10.3)	(.67)	(.10)	(.06)	(.16)	(125)	(134)	(104)	(.11)	(10)
	5.5		2,600	300	2.63	0.937	0.24	0.15	8.06	204	387	94	0.54	15
					(1.48)	(.57)	(.14)	(.10)	(.22)	(37)	(62)	(14)	(.10)	(6.9)
	3.4	16	4,800	560	0.75	1.01	0.31	0.23	8.17	179	357	85	0.45	9.8
					(1.42)	(.89)	(.27)	(.21)	(.28)	(33)	(49)	(14)	(.04)	(6.1)
	1.8	28	29,000	5000	0.73	1.10	1.04	0.80	8.08	175	418	104	0.57	13.0
					(.98)	(.61)	(1.05)	(.65)	(.27)	(28)	(68)	(39)	(.07)	(6.5)
	0.1	12	-	-	7.56	0.46	7.16	4.40	7.46	130	237	109	.97	82
					(2.69)	(0.21)	(4.6)	(2.01)	(0.25)	(15)	(34)	(34)	(.20)	(70)
													ALBN**	
1967	6.7	6	850	-	3.60	0.26	0.25	0.21	8.16	186	354	104	2.05	14.3
					(2.62)	(.26)	(.11)	(.12)	(.19)	(27)	54	(11)	(2.42)	(6.7)
	5.5	12	580	-	0.10	1.12	0.43	0.30	8.25	171	291	111	0.28	24
					(.20)	(1.82)	(.39)	(.13)	(.23)	(20)	(27)	(22)	(.28)	(8.8)
	3.4	10	21,000	-	3.38	0.75	0.81	0.79	7.93	181	439	99	1.95	12.5
					(2.48)	(.77)	(.51)	(.50)	(.26)	(16)	(96)	(20)	(1.6)	(3.6)
	2.7	4	74,000	-	3.25	0.46	.90	.79	8.14	189	410	87	1.63	13.4
					(1.32)	(.06)	(.02)	(.03)	(.21)	(4)	(46)	(11)	(.95)	(9.3)

TABLE C.2 (Continued)

DATE	MILE	N	Col./ 100 mL	F.Col./ 100 mL	NH_3 mg/L	NO_3 mg/L	TP mg/L	SP mg/L	pH	Alk mg/L	Hard mg/L	Cl mg/L	ALBN** mg/L	COD mg/L
	1.8	15	95,000	-	3.38	2.11	1.54	1.33	7.85	172	417	112	2.40	17.6
					(2.4)	(.93)	(.85)	(.80)	(.27)	(21)	(67)	(22)	(1.81)	(7.8)
	0.1	5	160,000	-	8.80	0.35	4.78	2.18	7.28	137	229	80.6	5.12	60.2
					(1.51)	(.31)	(1.52)	(1.41)	(.25)	(20)	(49)	(9.3)	(3.0)	(11.8)
													Chl-a ug/L	SS
1974	8.7		18,000	530	2.60	0.81	0.09	0.05	8.27	235	361	104	8.47	35.0
	6.0	17	78,000	1100	14.9	2.59	0.06	0.04	8.18	379	626	213	9.52	17.1
	5.5	16	58,000	880	9.66	2.01	0.08	0.06	8.24	268	594	159	9.49	23.4
	3.4	17	107,000	7500	3.41	1.36	0.13	0.11	8.15	166	493	127	5.42	8.8
	2.7	17	94,000	1400	3.20	0.92	0.12	0.09	8.27	156	487	125	6.54	9.2
	1.8	17	380,000	2900	4.18	1.13	0.35	0.32	8.11	163	442	109	8.78	20.0
	0.1	13	900	10	21.94	1.13	0.31	0.13	7.92	148	247	134	6.27	21.6
1975	1.8		420,000	42,000	4.0	2.08	0.38	0.325	7.8	146	410	95	6.0	8
					(1.55)	(1.57)	(.19)	(.17)	(.27)	(24)	(86)	(23)	(5.4)	(5)

TABLE C.2 (Continued)

DATE	MILE	N	Col./ 100 mL	F.Col./ 100 mL	NH_3 mg/L	NO_3 mg/L	TP mg/L	SP mg/L	pH	Alk mg/L	Hard mg/L	Cl mg/L	SS mg/L	Chl-a ug/L
1976	8.7	10	3,400	128	1.7	0.52	0.08	0.053	8.1	265	396	45	17	4.1
					(1.6)	(.71)	(.04)	(.034)	(.11)	(47)	(64)	(39)	(2.5)	(1.6)
	7.8	10	6,100	190	1.4	0.43	0.123	0.080	8.0	242	367	38	27	6.9
					(1.2)	(.60)	(.072)	(.058)	(.28)	(52)	(60)	(38)	(37)	(6.7)
	6.5	10	12,800	420	1.4	0.67	0.071	0.033	8.1	210	720	85	80	9.5
					(1.3)	(.87)	(.041)	(.016)	(.07)	(34)	(144)	(14)	(112)	(8.0)
	6.0	10	10,600	390	5.1	2.0	0.100	0.058	8.1	333	748	46	20	9.5
					(3.1)	(.38)	(.09)	(.038)	(.08)	(77)	(129)	(24)	(24)	(4.6)
	5.5	10	1,170	27	4.0	2.0	0.061	.025	8.1	222	540	56	23	8.1
					(1.85)	(.59)	(.047)	(.014)	(.10)	(42)	(99)	(23)	(24)	(4.7)
	3.4	10	7,700	2300	2.3	0.84	0.170	0.089	8.1	170	492	38	8.5	6.8
					(1.86)	(.56)	(.079)	(.073)	(.07)	(34)	(95)	(28)	(11)	(3.2)
	2.7	10	11,000	520	2.14	0.56	0.128	0.105	8.3	163	478	34	12	12.7
					(2.24)	(.70)	(.076)	(.069)	(.26)	(37)	(72)	(26)	(17)	(14.4)
	1.8	10	55,000	3400	2.68	1.11	0.363	0.315	8.0	163	433	21	6	8.7
					(1.60	(.65)	(.093)	(.107)	(.04)	(32)	(103)	(19)	(3)	(8.3)
	0.1	10	2,100	37	4.17	0.15	0.806	0.47	7.9	163	267	36	44	6.8
					(2.53)	(.22)	(.80)	(.57)	(.36)	(42)	(73)	(26)	(54)	(3.9)

* Data from Annual Sanitary Surveys in HRCA. Surveys where made by Hamilton Municipal Labs for the HRCA. Data for 1975 and 1977 on, and for standard deviations for 1974 were not summarized at the time of this writing.

** ALBN = Albumin Nitrogen, mg/L

TABLE C.3

WATER QUALITY OF RED HILL CREEK AT TWO POINTS FROM 1967-1976*

DATE	MILE	N	Col./ 100 mL	F.col/ 100 mL	NH_3 mg/L	NO_3 mg/L	TP mg/L	SP mg/L	pH	Alk mg/L	Hard mg/L	Cl mg/L	SS mg/L	Chl-a ug/L
1976	5.5		1170	27	4.0	2.0	0.061	0.025	8.1	222	540	56	23	8.1
					(1.85)	(.59)	(.047)	(.014)	(.10)	(42)	(98)	(23)	(24)	(4.7)
1975 Jun-Aug		9	16,700	2000	4.13	1.25	0.094	0.057	8.01	205	580	158	40	7.2
					(1.29)	(.42)	(.034)	(.038)	(.03)	(67)	(173)	(47)	(27)	(3.6)
1974	5.5	16	58,000	900	9.66	2.01	0.08	0.06	8.24	268	594	159	23.4	9.49
					-	-	-	(.06)	(.19)	(40)	(176)	-	(17.0)	(6.53)
1973 May-Jun	5.5	11	4000	290	10.2	1.12	0.17	.038	8.04	269	562	121	-	10.1
					(5.06)	(.50)	(.19)	(.038)	(.10)	(18)	(71)	(43)		(4.1)
Jun-Aug 1972	5.5	11	2200	200	3.06	2.18	0.20	0.12	7.57	218	484	143	-	4.31
					(2.0)	(.96)	(.34)	(.29)	(.25)	(34)	(65)	(27)		(2.01)
Jun-Aug 1971	5.5	8	370	300	5.03	2.13	0.15	0.13	7.7	228	571	242	-	-
					(3.10)	(.70)	(.13)	(.08)	(.18)	(30)	(57)	(53)		
Mar-Sep 1970	5.5	20	1700	210	6.00	1.45	0.32	0.18	7.82	204	398	153	-	-
					(5.04)	(1.13)	(.27)	(.12)	(.36)	(65)	(66)	(42)		
May-Nov 1969	5.5	20	-	-	4.85	1.17	0.18	0.11	-	-	-	-	-	-
					(5.27)	(.84)	(.08)	(.06)						
May-Nov 1968		26	2600	300	2.63	0.93	0.24	0.15	8.06	204	387	94	F 0.54	
					(1.48)	(.57)	(.14)	(.10)	(.22)	(37)	(62)	(14)	(.10)	

TABLE C.3 (Continued)

DATE	MILE	N	Col. 100 mL	F.Col. 100 mL	NH_3 mg/L	NO_3 mg/L	TP mg/L	SP mg/L	pH	ALK mg/L	Hard mg/L	Cl mg/L	SS mg/L	Chl-a ug/L
May-Nov 1967	5.5	23	580	-	0.10 (0.20)	1.12 (1.82)	0.43 (.39)	0.30 (0.13)	8.25 (.23)	171 (20)	291 (27)	112 (22)	COD 24 (8.8)	ALBN 0.28 (.20)
													SS	Chl-a
1976	1.8	9	55,000	3400	2.68 (1.60)	1.11 (0.65)	0.363 (.093)	0.315 (.107)	8.0 (.04)	163 (32)	433 (30)	-	6 (3)	8.7 (8.3)
Jun-Aug 1975	1.8	9	420,000	42,000	3.96 (1.55)	0.92 (.55)	0.38 (.18)	0.33 (.17)	7.82 (.27)	146 (24)	410 (86)	95 (22.5)	8.1 (5.0)	5.6 (5.7)
1974	1.8	17	376,000 -	3000	4.18 -	1.13 -	0.35 -	0.32 (.19)	8.11 (.18)	1.63 (27)	442 (58)	109 -	20 (8.4)	8.78 (5.06)
May-Jul 1973 9 samples			270,000	40,000	12.6 (11.2)	0.60 (.34)	1.38 (1.52)	1.25 (.26)	7.90 (.21)	176 (53)	395 (99)	95.3 (17.0)	-	11.0 (13.5)
Jan-Oct 1968	1.8	28	29,000	5000	0.73 (.98)	1.10 (.61)	1.04 (1.05)	0.80 (0.65)	8.08 (.27)	175 (28)	418 (68)	104 (39)	F 0.57 (.07)	COD 13.0 (6.5)
May-Nov 1967	1.8	15	95,000	-	3.38 (2.4)	2.11 (.93)	1.54 (.85)	1.33 (.80)	7.85 (.27)	172 (21)	417 (67)	112 (22)	ALBN 2.40 (1.81)	17.6 (7.8)

* Data from Annual Sanitary Surveys in the HRCA. No data gathered at Mile 1.8 for 1969-1972
ALBN = Albumin Nitrogen

TABLE C-4

WATER QUALITY DATA FOR ANCASTER CREEK*

DATE	MILE	Col./ 100 mL	F.Col./ 100 mL	NH_3 mg/L	NO_3 mg/L	TP mg/L	SP mg/L	pH	Alk mg/L	Hard mg/L	Cl mg/L	SS mg/L	Chl-a ug/L
1976	0.8	10,000	170	0.049 (.027)	1.46 (.43)	0.055 (.058)	0.025 (.032)	8.2 (.14)	220 (15.3)	214 (18)	60 (6.5)	22 (17)	3.3 (1.2)
1975	0.8	2100	220	0.029 (.014)	1.34 (.39)	0.067 (.045)	0.019 (.016)	8.1 (.07)	210 (15)	301 (80)	59 (15)	21 (14)	3.0 (.9)
1974	0.8	21,000	7100	0.05	1.65	0.08					54		
1974	3.1	4000	840	0.03	3.17	0.09					57		
1974	4.0	13,000	1200	0.11	3.42	0.07					55		
1974	5.1	1000	300	0.08	2.53	0.07					47		
1974	5.5	3600	700	0.05	0.42	0.18					50		
1974	7.3	7400	1300	0.11	0.74	0.13					54		

* From Sanitary Survey in the HRCA. Note - data for 1968-1973 are available, but not summarized.

TABLE C-5a

TOTAL PHOSPHORUS IN SPENCER CREEK
AT HIGHWAY NO.8 CROSSING, DUNDAS, 1964-76

YEAR	N	X	s
64	2	.059	.08
65	16	.303	.150
66	22	.254	.260
67	21	.844	2.18
68	25	.114	.116
69	23	.182	.294
70	22	.104	.113
71	25	.134	.329
72	20	.196	.311
73	11	.063	.032
74	12	.132	.182
75	11	.095	.074
76	10	.063	.029

TABLE C-5b
WATER QUALITY IN 1975-76 SPENCER CREEK*

DATE	MILE	N	Col./ 100 mL	F.Col./ 100 mL	NH_3 mg/L	NO_3 mg/L	TP mg/L	SP mg/L	pH	ALK mg/L	Hard mg/L	Cl mg/L	SS mg/L	Chl-a ug/L
1976	2.4		4100	260	.038 (.023)	.575 (.158)	.066 (.05)	.041 (.049)	8.3 (.13)	240 (10)	269 (33)	26 (9)	14 (9)	3.5 (2.9)
1975	2.4	21	3400	860	0.051 (.027)	.70 (.24)	0.097 (.068)	0.048 (.036)	8.2 (.16)	212 (30)	294 (37)	39 (13)	32 (31)	4.1 (2.0)

* From Sanitary Survey in HRCA. Data for other years and points are available but not summarized.

TABLE C.6

DATA FOR VARIOUS STREAMS SUMMER, 1977 (JULY - THANKSGIVING)*

		REDHILL CREEK (at King St.)			GRINDSTONE CR. (at Hidden Valley)			CHEDOKE CR. (at 403-Toronto ramp)			CHEDOKE CR. (bridge at landfill)			GLEN ROAD (manhole at over flow)			GLEN ROAD (at iron grates)		
		$\bar{X}$	s	N	$\bar{X}$	s	N	$\bar{X}$	s	N	$\bar{X}$	s	N	$\bar{X}$	s	N	$\bar{X}$	s	N
Colour		33	6	3	34	12	18	42	38	35	106	250	40	84	52	8	100	35	5
Turbidity		22	5	3	6	9	18	102	243	35	88	216	40	37	22	8	44	21	5
F TOC		-	-	-	10	3	18	7	4	35	10	4	40	39	55	8	25	17	5
TOC		4	2	5	13	5	21	12	9	38	17	14	40	65	72	8	59	44	5
BOD	mg/L	6	4	6	6	4	27	8	9	31	20	19	39	-	-	-	-	-	-
COD		-	-	-	26	9	8	31	32	35	51	53	33	170	68	7	193	171	5
SS		118	193	6	40	76	29	420	800	33	192	475	37	-	-	-	-	-	-
Phenol ug/L		1	0	3	0.8	0.6	15	0.8	0.6	26	5	8	26	48	49	4	-	-	-
TKN		0.61	0.02	3	0.82	0.18	18	1.29	1.24	31	3.3	2.7	32	13.4	10	7	14.1	3.8	4
NO_2		0.014	0.008	3	0.043	0.03	18	0.016	0.016	31	0.059	0.019	33	0.163	0.222	7	0.111	0.105	4
NO_3		0.910	0.04	3	2.29	0.68	18	1.24	0.56	31	1.43	0.61	33	0.65	0.815	7	1.20	1.56	4
NH_3	mg/L	0.010	0.007	3	0.029	0.019	18	0.055	0.180	31	1.53	1.30	32	3.7	3.5	6	7.8	4.1	4
TP		0.18	0.31	9	0.35	0.17	27	0.44	0.71	40	0.71	0.81	42	1.88	1.32	6	2.11	0.42	4
SP		0.008	0.003	3	0.22	0.10	17	0.134	0.076	31	0.25	0.28	31	0.83	0.74	6	0.58	0.21	4
Cl		64	18	6	140	60	18	152	62	25	95	35	30	-	-	-	-	-	-
Cond uS/cm		970	45	3	600	66	17	720	130	34	707	207	20	373	305	4	-	-	-
pH		8.0	0.2	6	8.7	0.5	18	8.5	0.6	23	7.9	0.4	28	-	-	-	-	-	-
Cu	mg/L	0.01	-	3	0.01	-	2	0.03	0.02	16	0.09	0.09	21	0.08	0.03	4	0.08	0.02	4
Ni		0.02	-	3	0.02	-	2	0.02	-	16	0.03	0.03	21	0.02	-	4	0.10	0.08	4

Table C-6 (continued)

		REDHILL CREEK (at King St.)			GRINDSTONE CR. (at Hidden Valley)			CHEDOKE CR. (at 403-Toronto ramp)			CHEDOKE CR. (bridge at landfill)			GLEN ROAD (manhole at over flow)			GLEN ROAD (at iron grates		
		X	s	N	X	s	N	X	s	N	X	s	N	X	s	N	X	s	N
Pb		0.03	-	3	0.03	-	2	0.02	0.01	16	0.03	-	21	0.05	0.04	4	0.08	0.05	4
Zn		0.02	0.1	3	0.02	-	2	0.06	0.08	16	0.17	0.12	21	0.23	0.09	4	0.67	0.58	4
Cd	mg/L	0.005	-	3	0.005	-	2	0.01	-	16	0.005	-	21	0.005	-	4	0.01	-	4
Cr		-	-	-	0.02	-	2	0.02	0.02	15	0.02	-	21	0.07	0.02	4	0.05	0.03	4
Mn		-	-	-	0.10	0.11	2	0.12	0.13	15	0.10	0.07	21	0.07	0.04	4	0.12	0.06	4
Fe		-	-	-	0.15	0.04	2	5.4	8.4	15	3.8	3.8	16	2.2	1.9	4	7.1	4.6	4
A		-	-	-	-	-	-	0.002	0.001	12	0.003	0.001	13	0.002	0.000	4	0.003	0.001	4
Sol. Ext. Oil and Grease		-	-	-	-	-	-	3	-	1	2	0	2	-	-	-	-	-	-

* Gathered by McMaster Experience '77 Group

APPENDIX A.4

MODIFICATIONS TO ANNUAL STORM WATER LOADINGS TO HAMILTON HARBOUR USING THE SWMM RUNOFF MODEL

The continuous SWMM runoff model has been applied by Robinson et al (1981) to estimate the annual export of BOD_5, total nitrogen (TN), total phosphorus (TP) and suspended solids (SS) from various Hamilton watersheds. This model estimates the dust buildup during dry weather periods between storms and the portion of this buildup which is washed off during a storm. Some of its capabilities and weaknesses have been reviewed in Section 5 of this report in the discussion of Marsalek's work.

The main part of the work of Robinson et al (1981) involved estimating the runoff patterns, chemographs and pollutant loads for the Chedoke Creek basin. Various sub-catchments in the Chedoke Creek watershed were gauged to measure hydrographs. For chemographs, six storms were sampled in Chedoke Creek below Glen Road. The total number of samples, which include combined sewer runoff from the three small catchments plus Chedoke Creek runoff, was approximately 36.

Extensive efforts were made to calibrate the continuous SWMM model to give predictive exports equal to the measured. The main calibration parameters used were the portion of rainfall lost to infiltration, the rate of accumulation of dust and solids, and the ratio of pollutant (BOD_5, TN, TP) mass to mass of solids in accumulating dust and dirt.

For application to the storm sewers of Hamilton, the whole watershed above and below the escarpment was divided into seven sub-basins and around 95 sub-catchments. The sub-basins above the escarpment drained into either Chedoke Creek or into Red Hill Creek, while the majority of areas below the mountain drain into combined or separate sewers. During storms, when the majority of overflow gates are rapidly opened, the combined sewers flow directly into the harbour. Under other conditions, both separate and combined sewers flow into the Hamilton sewage treatment plant.

The modelled flow for Chedoke Creek was calibrated with data gathered by Robinson et al (1981) and for Red Hill Creek with data from approximately 10 independent storms using flow rates measured at 50-minute intervals by the Water Survey of Canada continuous gauge. Since no measurements of downtown sewer overflows were available, these sub-catchments were calibrated by estimating imperviousness from maps showing single family, institutional and industrial areas and estimating the amount of depression storage in each watershed. The overall runoff coefficients calculated for each watershed (Table A.4.1) represent the difference between the amount of rainfall and the amount of infiltration through grassed areas plus infiltration from depression storage plus evaporation. It was also assumed that all runoff from the Hamilton storm water system flowed directly to the harbour.

Runoff volumes and resulting pollutant exports from each sub-watershed were estimated using rainfall data from the Hamilton Airport for each summer (May 1 to October 31) for the years 1970 to 1978 inclusive and for 1980. The pollutant export estimates are based exclusively on export-rainfall relationships observed in Chedoke Creek. The accumulation rates for suspended and settled solids are adjusted so that predicted exports from Chedoke Creek equalled the measured. Similarily, the ratios of BOD_5 to solids, TN to solids and TP to solids were adjusted to give the observed BOD_5, TN and TP exports from the Chedoke Creek watershed. Application of these calibration factors to other watersheds assumes that these other watersheds have characteristics similar to Chedoke Creek.

The calculated loadings from the Hamilton Harbour storm sewers, Red Hill Creek and Chedoke Creek are given in Table A.4.1. Chedoke Creek does not empty directly into the harbour, but rather into the east pond of Cootes Paradise. The total area serviced by the downtown sewers is the same as used in Section 2.2 of this study (see Table 2.1), but the areas of individual catchments have been allocated somewhat differently because of a more detailed analysis of the storm sewer system, particularly in the Wellington Street catchment and the area westward towards Queen Street.

The new storm water loading estimates for BOD_5, TP, TN, and SS are compared with those in Table 6.1 of this report in tables A.4.2 to A.4.5. For the downtown storm water overflows, the new estimates are 3.7 times higher for BOD_5, 37 times for SS and 5 times for TP and approximately the same for TN. The newer estimates of flow are 1.4 times higher - a not unexpected difference given the fact that the flow estimate in Table 6.1 was based upon an assumed relationship between rainfall and runoff volumes giving a gross runoff coefficient of 0.27 compared to the 0.46 from the present SWMM simulation (Table A.4.1). The Chedoke inputs to Cootes Paradise represent 5%, 40%, 8%, 17% and 4% of the export from Cootes to the harbour for BOD_5, SS, TN, TP and flow, respectively. These values appear to be reasonable except for suspended solids - either the input to Cootes is too high or the export from Cootes is too low.

At first glance, the SWMM estimates of daily exports from Red Hill Creek compare favourably with those in this study except for suspended solids. However, since the flow volume for the six-month period May to October is only 30% of the average annual flow, the SWMM loading estimates for this period seriously underestimate the average annual loadings. By setting the volume of annual runoff and hence the runoff rate equal to that calculated in this study, a new average annual loading estimate is calculated (Table A.4.2d). This flow correction was not applied for the winter period for the downtown sewers since it is assumed that much of the winter snow will melt sufficiently slowly that the melt waters will be intercepted and carried to the sewage treatment plant. This correction is needed, however, for Red Hill Creek because, despite the summer and winter precipitation being approximately equal in quantity (the 10-year summer average used by Robinson was 17.8 inches versus the annual average of 35 inches in Table 3.2 of this study), the runoff coefficient increases dramatically from a summer value of 0.15 (Table A.4.1) during spring snow melt over frozen ground.

The revised SWMM estimates for Red Hill Creek are 1.9 to 2.8 times higher than those in the study for BOD_5, TN and TP but are 16 times higher for SS. This pattern is similar to that for the downtown storm sewers. Since the annual estimates of suspended

solids are mainly a function of the rate of dirt and dust accumulation (a calibration parameter), there are not any significant flow concentration-induced errors, (see Appendix A.2), buried in the SWMM estimates. Therefore the differences have to be due to the average concentration of suspended solids observed in the Chedoke Creek data.

The calibrated suspended solid concentration from SWMM for Chedoke Creek is approximately 1,500 mg/L based on approximately 36 samples taken during storm water runoff. This value is likely affected by erosion from the golf course and by storm water samples taken from behind weirs, where SS concentrations are higher. The downtown storm water estimate of about 57 mg/L is based on 15 samples taken from the overflows from Ottawa, Kenilworth and Parkdale sewers during summer storms and non-storm periods. The Red Hill estimate of 91 mg/L is based on six samples taken on the same days as industrial overflows. The suspended solid concentrations in downtown storm waters should be significantly lower than that calculated for Chedoke Creek because the main source of particulates is atmospheric fallout. The estimate of the average flow rated concentration in storm water can range from about 100 mg/L to 1500 mg/L, resulting in estimated loadings to the harbour from 140,000 to 300,000 kg/d. This author believes that the best estimated loading for suspended solids is around 173,000 kg/d based on a suspended solid concentration of 250 mg/L for the downtown sewers and 400 mg/L for Red Hill Creek.

The SWMM generated estimates for BOD_5 are recommended for future use. However, the total phosphorus estimates in Table 6.1 are recommended at this time as the calibrated TP concentrations at Red Hill Creek are judged to be too high and the downtown sewerage overflows values are dominated by soluble forms of phosphorus rather than particulate forms. Nitrogen numbers in Table 6.1 are recommended. The differences with the SWMM estimates are inconsequential.

The loading estimates for the parameters are given in Table A.4.3. This is a summary of Table 6.1 and of the SWMM estimates and incorporates changes to Table 6.1 described in the text but not tabulated. This data is then expressed on an average concentration basis for the various influent sources in Table A.4.5. Expressed in this fashion, it illustrates the significance of different combinations of sources as a driving force for maintaining pollutant concentrations in the harbour.

Table A.4.1: Estimated Loadings to Various Sub-Watersheds Using SWMM Rainfall-Runoff Model (Robinson et al, 1981)

Drainage Basin	Computer Coding	Area (mi^2/ha)	Loading (kg/d) BOD_5	SS	TN ($TKN+NO_3$)	TP	Flow (m^3/d)	Runoff Coefficient
(a) Hamilton Storm Sewers								
Queen	45001	0.26(67.2)	6.9	409	2.0	0.63	774	0.471
Hess	46001	0.253(65.5)	7.8	468	2.3	0.73	1,010	0.606
James	47001	0.159(41.3)	6.5	375	2.5	0.59	413	0.410
Catherine	48002	0.094(24.3)	2.6	162	0.8	0.25	321	0.543
Ferguson	48001	0.285(74.1)	14.6	791	4.1	1.30	810	0.448
Wellington	49001	1.56(404)	74.5	4,140	18.1	6.81	4,800	0.488
Wentworth	85001	1.31(340)	66.9	3,900	19.8	6.32	2,650	0.319
Hillyard	86101	0.116(29.9)	6.9	404	2.2	0.84	350	0.482
Birch	86001	0.422(109)	25.2	1,440	7.9	2.65	880	0.331
Gage	58001	2.45(636)	196.	11,400	59.5	19.3	7,450	0.480
Ottawa	59001	0.381(98.7)	31.8	1,700	9.2	3.06	1,550	0.643
Kenilworth	62001	1.04(268)	112.	7,200	34.8	11.0	3,110	0.475
Strathearne	63001	1.14(295)	102	6,540	31.6	10.1	3,500	0.486
Parkdale	65001	0.701(182)	82.5	4,890	25.1	8.40	2,170	0.490
Dunn	76001	0.42(109)	40.0	2,100	10.8	3.45	691	0.259
TOTAL		10.59(2740)	773.	45,900	231.	75.5	30,500	0.455
(b) Chedoke Creek to Cootes Paradies								
Storm Sewers (Ewan St., McMaster, Forsythe)	10001	0.730(189)	18	1,800	9.8	2.9	2,700	0.345
Chedoke Creek	28110	9.62(2490)	109	13,500	68.6	20.3	13,200	0.217
Total		10.4(2680)	127	15,300	78.4	23.1	15,900	0.249
(c) Red Hill Creek to Hamilton Harbour								
Whole	92140	25.6(6640)	622	36,800	186.	57	25,000	0.154

Table A.4.2. Comparison of New Loadings With Other Data

(a) Data from Table 6.1 for Hamilton Storm Sewers

Source	BOD_5 (kg/d)	SS (kg/d)	TN (kg/d)	TP (kg/d)	Flow (m^3/d)
Robinson	773	45,900	230	75.5	30,500
Table 6.1	210	1,240	168	15	21,800
Ratio Robinson to Table 6.1	3.7	37	1.4	5.0	1.4

(b) Average Concentrations for Hamilton Storm Sewers

Description	BOD_5 (mg/L)	SS (mg/L)	TN (mg/L)	TP (mg/L)
Inferred from Robinson	25	1500	7.5	2.5
Inferred from Table 6.1	10	57	7.7	0.69
Measured James St.*				
(a) July 6 - Storm 1	46-49	280-70	-	0.1-1.2
(b) July 6 - Storm 2	32-80	180-90	-	0.1-6.7
(c) July 6 - Storm 3	24-80	350-47	-	0.1-0.51
(d) July 7	35-40	290-70	-	0.2-0.36
(e) Aug. 8	19-30	228-48	-	-
(f) Nov. 7	42 (Aug.)	54 (Aug.)	-	-
(g) Nov. 10	38 (Aug.)	250-40	-	-

* Range given from peak of hydrograph to its ebb.

(d) (ii) Average Concentration of Red Hill Loadings to Hamilton Harbour

Description	BOD_5 (mg/L)	SS (mg/L)	TN (mg/L)	TP (mg/L)
SWMM	25	1500	7.4	2.3
Table 6.1	13	91	3.2	0.8

Table A.4.3. Loadings (kg/d) to Hamilton Harbour in 1977 - Comparison of Table 6.1 and SWMM Estimates

Source	TP T.6.1	TP SWMM	TN T.6.1	TN SWMM	BOD_5 T.6.1	BOD_5 SWMM	SS T.6.1	SS SWMM	Flow (m^3/d) T.6.1	Flow (m^3/d) SWMM
WWTP*	371	371	12,300	12,300	6,250	6,250	12,500	12,500	310,000	310,000
Industrial*	0	0	8,300	8,300	6,780	6,780	76,700	76,700	0	0
Streams	98	221	700	1,060	1,800	2,800	12,400	12,800	20,700	20,700
Central Business District	15	76	168	231	210	773	1,240	45,900	21,800	30,500
Cootes*	140	140	1,000	1,000	2,700	2,700	38,000	38,000	345,000	345,000
TOTAL	624	808	22,468	22,891	17,740	19,303	140,840	301,100	883,800	892,500

* Loadings and flows from these sources are unchanged ~~of~~ as SWMM deals only with streams and sewers.

Table A.4.4. Analysis of Loadings Incorporating SWMM Stormwater Estimates

(a) Comparison with Estimates of Table 6.1

Description	TP (kg/d)	TN (kg/d)	BOD_5 (kg/d)	SS (kg/d)
Estimates incorporating SWMM	808	22,900	19,300	301,00
Values for Table 6.1	624	22,500	18,000	140,000
Ratio Revised to Table				
Ratio SWMM Estimates to Table 6.1	1.3	1.0	1.1	2.1

(b) Percentage of Inputs from Major Sources

Source	TP (%)	TN (%)	BOD_5 (%)	SS (%)
Municipal	46	54	33	4
Industrial	0	36	35	25
Streams	29	5	15	43
Hamilton Storm Sewers	9	1	3	15
Cootes Paradise	18	4	14	13

Table A.4.5. Average Concentration (mg/L) in Different Inflows to Hamilton Harbour - Comparison of Estimates from Table 6.1 and SWMM

Source	TP		TN		BOD_5		SS	
	T.6.1	SWMM	T.6.1	SWMM	T.6.1	SWMM	T.6.1	SWMM
WWTP*	1.2	1.2	39.7	39.7	20.2	20.2	40.3	40.3
Streams	0.31	1.07	3.38	5.12	8.7	13.5	60.0	61.8
Streams + Cootes	0.43	0.65	3.1	3.7	8.2	10	91	300
Hamilton Storm Sewers	0.69	2.3	7.7	7.1	9.6	24	57	1400
All Inflows Except Industrial	0.71	0.89	16.1	16.4	12.4	14	55.2	244
All Inflows Including Industrial	0.71	0.89	25.4	25.7	20.0	21.5	160	330